SUCCESSIVE CROPPING OF POLYETHYLENE MULCHED VEGETABLES AS INFLUENCED BY IRRIGATION METHOD AND FERTILIZER RATE

BY

GEORGE H. CLOUGH

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GEORGE H. CLOUGH

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Chairman: S. J. Locascio
Major Department: Horticultural Science

Broccoli (Brassica oleracea L. var. italica), tomato (Lycopersicon esculentum Mill.) or squash (Cucurbita pepo L. var. melopepo) and broccoli were produced in succession on the same black polyethylene mulched beds at 2 locations with different soil types. Yields of the first broccoli crop were earlier and higher with drip than overhead irrigation and increased as N-K rate increased from 135-202 to 270-404 $kg \cdot ha^{-1}$. On a fine sandy soil, yields of 2nd and 3rd crops produced with residual or concurrent fertilization increased with an increase in N-K rate. On a loamy fine sandy soil, yields also increased as the rate of residual N-K increased but yields of 2nd and 3rd crops did not respond to rate of concurrently applied N-K. Yields of 2nd and 3rd crops were higher with concurrent than residual fertilization except total tomato yields were similar with either application time on the loamy fine sand. With drip irrigation and concurrent weekly fertigation, yields equaled or exceeded those

obtained with preplant fertilization and overhead irrigation. Yields of crops grown with residual nutrients were higher with overhead than drip irrigation. Yields of the 3rd crop, broccoli, were higher following squash than tomato.

A significantly higher soil moisture content was maintained throughout the mulched bed area with drip than with overhead irrigation. Nutrient leaching was greater with drip although 45% less water was applied than with overhead.

Most soil nutrient concentrations were higher with overhead than drip irrigation and with concurrent than residual fertilization, and increased with an increase in N-K application rate. With overhead irrigation, nutrient concentrations were higher at the bed center than side and decreased with depth. With drip irrigation, concentrations were higher at the side than center of the bed and decreased with an increase in depth at the side.

Successive production of polyethylene mulched vegetables resulted in more complete utilization of fertilizer, mulch, fumigant and fuel. Production costs would be reduced by prorating material and labor costs over more than one crop. With drip irrigation, water use was lower than with overhead.

CHAPTER 1
INTRODUCTION

Vegetable production is an important component of Florida's agricultural industry. Utilizing almost 170,000 ha state-wide, the value of commercial vegetable sales in 1984-1985 was 1 billion dollars (33). In north and west Florida, more than 37,600 ha of vegetables were harvested during the same time period. The value of this production exceeded 100 million dollars.

While 70% of the farms in the state grossed less than $20,000 in 1982, more than 80% of the farms in north and west Florida fall into that category (16). Of these farms, only 14% produced vegetable crops. With limited farm size and low returns to livestock and field crop enterprises, vegetable production is an alternative for increasing farm income and providing local employment.

In general, returns to vegetable production in north and west Florida are lower than in other regions of the state. This is due in part to marketing, i.e., location and prices, but also results from deficiencies in crop management practices, principally low capital investment, poor technical skills and limited knowledge.

A reduction in capital inputs in conjunction with increased yields through the development of a reduced input/management vegetable production system may provide the catalyst needed to raise the current low level of vegetable production by the smaller-scale

producers, resulting in increased farm income and local employment opportunities (51). Additionally, as costs of inputs have increased significantly in recent years, returns to the larger-scale producer have decreased. Many commercial tomato producers are now interested in multiple cropping whereby the initial crop can be followed by other crops, further using the fumigants, mulch, and residual fertilizers to reduce the production costs for the subsequent crop (14,19,41,80,85).

The objective of this study is to examine the influence of 1) irrigation method, 2) rate and time of N-K application, and 3) crop succession on yield and plant mineral composition and soil chemical characteristics of successively-cropped, polyethylene-mulched vegetables.

CHAPTER 2
LITERATURE REVIEW

Influence of Mulch on Vegetable Production

The use of mulch has many advantages over bare ground culture. Emmert (27) examined the effects of several mulches, percent ground coverage, and irrigation on tomato and pole bean (Phaseolis vulgaris L. 'Kentucky Wonder') production. Yields of both crops generally were higher with mulch than without, with full than with partial plot coverage, and with sprinkler irrigation than without. Unstaked tomato fruit quality was improved, and yield increases up to 33% were obtained with mulch. In late season plantings, black polyethylene mulch caused soil to become too warm, reducing seed germination and pole bean plant stands. Aluminum-laminated polyethylene resulted in better stands and more consistent yield increases but best results were obtained with aluminum-pigmented plastic. Spring pole bean plots were replanted without removal of mulch. Second crop yield on mulch was 650% higher than yields without mulch. Improved yields of all crops produced on plastic were attributed to moisture conservation and weed control.

In the first year of a 2-year study in north Florida, black polyethylene mulch was most economical for cantaloupe (Cucumis melo L. var. reticulatus Naud.) production, and clear and black mulches significantly increased earliness in cantaloupe and watermelon (Citrullus lanatus (Thunb.) Matsum. & Nakai) over white-on-black

mulch and unmulched controls (13). However, clear polyethylene mulch was most profitable for watermelon and sweet potato (Ipomoea batatus L.) and resulted in highest pole bean yield, while white-on-black resulted in highest yields of sweet potato and squash. All mulches were unfavorable to southern pea (Vigna unguiculata (L.) Waep.) due to Fusarium wilt in the mulched plots. In the 2nd year, highest yields of spring okra (Abelmoschus esculentus (L.) Moench), cantaloupe, cucumber (Cucumis sativus L.), butternut squash (Cucurbita maxima L.) and watermelon were obtained with clear polyethylene while aluminum-painted mulch resulted in highest sweet potato and fall okra yields. The use of black plastic mulch resulted in highest pole bean and summer squash yields but lowest yields of butternut squash. Black polyethylene mulch improved appearance and size of cauliflower (Brassica oleracea L. var. botrytis), cabbage (Brassica oleracea L. var. capitata), broccoli and lettuce (Lactuca sativa L.), and increased yields of cabbage, lettuce and broccoli by 9, 78 and 17%, respectively, over unmulched controls. Cauliflower plant stand was reduced with the black plastic but yields were similar to the unmulched controls. Increased yields and/or improved timeliness attributed to the use of mulch in vegetable production also have been reported for cantaloupe (47), cucumber (36,70,79), dry lima bean (Phaseolus limensis L.) (50), snap bean (50), lettuce (31), bell pepper (Capsicum annuum L. var. annuum) (57), yellow squash (17,79), zucchini squash (9), sweet potato (50), strawberry (Fragaria x ananassa (Duch.)) (76), tomato (28,36,40,45,50) and watermelon (11).

Estes et al. (28) evaluated the economic value of several soil management practices with staked tomato production. The use of mulch (plastic or straw) increased yields and net returns over standard cultivation practices. Highest initial gross revenues were realized with black plastic mulch while the highest net economic values of the various management practices also were associated with polyethylene mulch. Others (9) reported that increased productivity and decreased unit production costs offset higher zucchini squash production costs due to use of plastic mulch.

Effects of Mulches on Soil and Plant Environment

Everett (31) studied the influence of fertilizer rates and plastic mulch on the production of crisphead lettuce on mineral soil with seep irrigation. The use of plastic mulch increased yield, average head weight and number of heads weighing 0.77 kg or more, over unmulched control plots. In a high rainfall year (~27.5 cm over the 3-month sampling period), soluble salts in the upper 15 cm of the plant bed were reduced by 89 and 92% with low and high fertilizer rates, respectively, without mulch. In the same time period with the same fertilizer rates soluble salts were reduced only 3 and 26% in mulch covered beds. The author concluded that the primary effect of mulch on improved lettuce production was in reducing the leaching of plant nutrients.

A higher percentage of banded N and K was retained in a Kanapaha fine sand when strip mulch was applied over the band as compared to

unmulched soil (32). While higher levels of soluble salts, NO_3-N, NH_4-N and K were associated with strip mulch, particularly in early and mid-season, differences due to mulching were not as evident at the end of the bell pepper production season. With full-bed plastic or paper mulch and broadcast fertilizer application, mulch was not as effective in reducing nutrient leaching. Although soil NO_3-N concentrations were consistently higher with mulch than without, NH_4-N and K concentrations were lower under mulch than bare soil after the early sampling. However, soil total N concentrations (NH_4-N + NO_3-N) in full-bed mulched plots were higher or equal to those from unprotected beds, so higher rates of nitrification under mulch may have caused the observed differences. When yield differences occurred, the higher yields were obtained from mulched plots (57).

Fiskell and Locascio (32) reported higher soluble salts and NO_3-N, NH_4-N and K concentrations in a Chipley fine sand with strip mulch over banded fertilizer and with both paper and polyethylene full-bed mulches over broadcast fertilizer as compared to unmulched control plots. The differences were consistent throughout the 4-month sampling period. Significantly higher concentrations of nutrients remained in the mulch protected beds at the end of the watermelon production season while most nutrients had leached from the soil under the unmulched controls. Similar results (40) have been obtained for strip and full-bed mulch production of onion (Allium cepa L.) and tomato on an Immokalee fine sand in south Florida.

Full-bed plastic mulch on a sandy soil prevented significant movement of nutrients out of the soil profile (36). Nutrient leaching occurred in plots without plastic mulch, with NO_3-N concentrations at a deficient level to a depth of 15 cm both in the fertilizer band and next to the crop plants. Soil concentrations of soluble salts, NO_3-N, NH_4-N, P, K and Ca were higher with than without mulch at all depths sampled at the conclusion of the study.

On a loamy sand, soil NO_3-N concentrations were significantly higher at 15, 30 and 60 cm depths with white-on-black polyethylene mulch than without (45). However, at the 90 and 120 cm depths, soil NO_3-N concentration was higher under bare soil due to downward movement from the upper soil profile. Soil Ca and Mg concentrations in the upper 15 cm of the soil profile were higher with mulch than without; however, all levels were sufficient for good crop production. Since constant soil moisture was maintained by irrigation, the significantly higher tomato yields associated with the mulched plots were due to the more favorable distribution of nutrients in the soil profile.

In addition to reduced nutrient leaching, another of the principal effects associated with mulched crop production is increased soil moisture retention. With constant soil moisture maintained by overhead irrigation to the extent possible by using irrometers and frequent gravimetric determinations, white-on-black polyethylene mulch still increased soil moisture in a loamy sand to a depth of 30 cm, with differences extending below 75 cm in depth as compared to unmulched plots (45). Knavel and Mohr (50) reported

consistently higher soil moisture percentages to the 15 cm depth of a silt loam soil with black paper or black polyethylene mulches than with no mulch. The effect of clear plastic was inconsistent with moisture conserved only very early in the season. High soil temperatures underneath the clear film through most of the growing period apparently caused a high evapotranspiration rate and a continuous decline in soil moisture. Little difference in soil moisture was observed between clear polyethylene and bare soil later in the season; both were well below optimum soil moisture levels. The low soil moisture caused roots of tomato, muskmelon and squash to grow deeper in soils unmulched or covered with clear film than in soils covered with opaque materials. Roots of plants mulched with either black polyethylene or paper were very shallow and considerably longer. Soil temperature did not directly affect root distribution because unmulched soils were much cooler than soils mulched with clear polyethylene, and depth of root penetration was similar with both treatments. Soil temperatures were lower under opaque than transparent mulch but higher than without mulch. Soil moisture, however, was considerably higher than with clear film or unmulched soil. Soil moisture was the principal factor that modified root growth and distribution of tomato, muskmelon, squash and pepper in this study.

Courter and Oebker (18) reported that average minimum and maximum soil temperatures at a 10 cm depth were lowest under brown and black paper mulches, intermediate under bare soil and highest under black polyethylene film. Since yields of yellow and zucchini

squash were highest with black plastic, intermediate with paper mulches and lowest without mulch, the authors suggest that alteration of soil temperature is not a primary factor promoting crop yield with mulch.

Lippert et al. (55) found that black polyethylene and petroleum mulches substantially increased soil moisture retention to a 60 cm depth over clear mulch. The same researchers (89) reported soil temperatures at the surface and to a 30 cm depth increased less with black than with clear polyethylene or petroleum mulches during the day but that black polyethylene film retained more soil heat than the other mulches at night. In a sandy loam soil, the percentage available soil water at the 2.5 and 10 cm depths was significantly higher under opaque or clear polyethylene mulches than in bare soil or under paper mulch (56). In all cases, soil moisture was higher at the 10 cm than the 2.5 cm depth. Moisture loss from the mulched plots was substantially less than from the bare soil plots. After 10 days without rain or irrigation, average soil moisture levels were at 75% available water in the mulched plots and 35% in the unmulched plots. Highest day and night soil temperatures at a 2.5 cm depth were recorded under clear and clear-on-black paper polyethylene mulches, respectively, while lowest temperatures occurred under gray or kraft paper and polyethylene on either gray or kraft paper mulches. Other reseachers (76) reported that although the use of black polyethylene mulch increased strawberry leaflet elongation over nonmulched controls both with and without drip irrigation, neither soil water potential at the 20 cm depth of a sandy loam soil nor leaf

water potential or turgor were influenced by the presence or absence of black polyethylene mulch. Since soil temperatures over a 24-hr period at 7.5, 10 and 20 cm depths were significantly higher with mulch than without, the authors concluded that the effect of black polyethylene mulch on strawberry leaflet elongation was primarily due to increased soil temperature rather than modification of soil water status.

In 2 out of 3 years, yields of porous black woven polyethylene mulched grapes were higher than those obtained with herbicide or grass sod (87). By the 3rd year, yields with plastic mulch and herbicide treatments were similar but both were superior to grass sod. Since the mulch was permeable to air and water and all treatments were irrigated with drip, the effect of the black polyethylene probably was due to warmer soil temperatures under the mulch.

Mulch contributes to increased crop productivity by reducing losses to pests. A 66% reduction in cucumber belly rot accounted for 1/3 of the increased marketable yield obtained with black plastic mulch over bare ground controls (36). The polyethylene mulch decreased ground rot of unstaked tomato by 44% as compared to unmulched plots. Most of the fruit infection in the mulched plots was due to fruit contacting the soil beyond the mulch. In fall observational plots, tomato roots under plastic grew into areas of salt concentrations sufficiently high to be toxic to nematodes. This effect in the mulched plots prevented the decline and loss of plants which reduced yields by more than 50% in the unmulched plots. An

undesirable effect was noted in another trial, when southern blight (Sclerotium rolfsii) infestation of staked tomatoes was favored due to warmer soils under the black polyethylene mulch.

Polyethylene film or brown paper mulches did not influence populations of plant parasitic nematodes in a 2-year study with yellow squash in Georgia (17). The effects of mulches on yields were greatest in nonfumigated plots while the effects of fumigant were negligible under mulch. In nonfumigated plots, plants mulched with aluminum and white plastic films yielded significantly better than those in plots covered with brown paper or blue plastic. The use of polyethylene increased yields by 430 to 660% over nonmulched controls, while brown paper mulch resulted in a yield increase of 370%. Although soil fungi and nematodes were present in high numbers, the abundant root system concentrated at the soil surface under the mulch was sufficient to overcome the stress induced by pathogens as long as adequate moisture and nutrients were available. The authors concluded that polyethylene mulch could be substituted for soil fumigation with chemicals. In the same study, all film mulches significantly reduced watermelon mosaic virus in both plants and fruits. In both years, aluminum plastic mulch, and in the 2nd year, brown paper mulch reduced aphid infestation until vine growth obscured their reflective surfaces. However, brown paper mulch resulted in significantly increased pickleworm infestation in the first year. All mulches reduced serpentine leaf miner infestation by 50% in both years.

Squash foliage received less pickleworm damage when mulched with aluminum than with black polyethylene (79). However, pickleworm damage to cucumber foliage and fruit of squash and cucumber was not affected by type of mulch. Compared to black polyethylene mulch, infestation of aphids and banded and spotted cucumber beetles was reduced in both crops by use of aluminum and aluminized plastic mulches. Reflective aluminum and aluminized plastic mulches also reduced the number of potato aphids in tomato and the number of fruit injured by the brownstink bug as contrasted to white or black polyethylene mulch. However, early season plant height, fruit set·plant^{-1} and first harvest yield decreased significantly in plots with aluminum mulch. In southern pea, aphid infestation was reduced with use of aluminum and aluminized plastic mulches while leaf miner infestation was highest with black polyethylene mulch.

Effects of Irrigation on Crop Production and Soil Environment

Numerous researchers have demonstrated the value of irrigation in the production of vegetable crops. Emmert (27) reported average yield increases of 53 and 79% with and without plastic mulch due to overhead irrigation of fall pole bean. No yield difference was noted between irrigated and unirrigated ground tomatoes produced on the same Maury silt loam soil. However, on a fine sandy soil, Locascio and Myers (58) found overhead or drip irrigation increased tomato yields by 290% over unirrigated plots. In the wetter 2nd season of the study, no yield differences occurred between treatments in the

mulched plots, but tomato yields were lower with overhead than with drip irrigation or without irrigation in the plots without mulch.

In a tropical environment, unmulched tomato yields ranged from 50 to 78% higher with drip irrigation and 25% higher with furrow irrigation as compared to no irrigation, while fruit quality was unaffected by irrigation according to Lin et al. (53). Tomato plant height and marketable fruit yield increased with overhead, drip or furrow irrigation as compared to no irrigation in a 3-year study by Doss et al. (24). Only in a high rainfall year were plant height and yield not influenced by irrigation. The percentage of large fruit tended to be higher from irrigated than from nonirrigated plots while blossom-end rot was greater without irrigation. No difference in yield was found between the irrigation methods but water use was reduced by 55% with drip irrigation. In commercial production fields on a rocky marl soil in south Florida, higher tomato yields and a higher percentage of larger and smoother fruit were obtained with drip than with overhead irrigation (84). In a similar study on calcareous soils, yields of large-sized and total marketable mulched tomatoes were greater with drip than with overhead irrigation in both wet and dry production seasons (15). Water use with drip irrigation was reduced by 59 and 50% in the dry and wet years. Yield response of unmulched tomatoes was similar with drip irrigation resulting in more than a 2-fold increase in extra-large, large and total marketable fruit while water use was reduced by 33% as compared with overhead irrigation. Pole bean and sweet corn (Zea mays L. var.

saccharata) responded similarly to the 2 irrigation methods with water use reduced from 12 to 50% with drip irrigation.

On a loamy sand soil, initial yield of ridge gourd (Luffa acutangula Roxb.) was lower with drip than with overhead or furrow irrigation while late yields were higher (82). Total yields were similar with all irrigation methods. Early and total yields of round gourd (Citrullus vulgaris (Stocks) var. fistulassus Duthic and Fuller) and watermelon and total yield of long gourd (Lagenaria sicerarea (Molina) Standl.) were higher with drip than with furrow or overhead irrigation. Water use was reduced from 21 to 44% with drip as compared to the other irrigation methods. On a deep sandy soil, early yields of watermelon increased 810 and 1890% with overhead and drip irrigation, respectively, over unirrigated controls (26). Total yields were 133 and 109% higher with the same treatments. About 36% less irrigation water was used to produce the crop with drip irrigation than with overhead. In the same study, on a spodosol, early watermelon yields were 52% higher with drip irrigation than with overhead or no irrigation while total yields were not influenced by irrigation or irrigation method. Water application was 44% lower with drip than with overhead irrigation.

Mulched strawberry yields were similar with drip, sprinkler and furrow irrigation in a high rainfall year according to Myers and Locascio (67). However, drip irrigation used only 50% of the water quantity of sprinkler or furrow irrigated plots. Soil moisture content in the rooting zone was maintained near field capacity on a continual basis with drip irrigation. While sprinkler and furrow

irrigation were effective in returning soil moisture content to field capacity when applications were made, a gradual depletion almost to the deficit level of the unirrigated check occurred before the next application. Soluble salts moved towards the upper center part of the beds with sprinkler and furrow irrigation and in the unirrigated check plots while significant movement was not detected in the drip irrigated beds. With all fertilizer applied prior to planting, strawberry yields increased 39% with drip or overhead irrigation as compared to nonirrigated controls in another study by Locascio and Myers (59). When part of the fertilizer was applied with the drip irrigation water, fruit yields were 20-25% greater than with overhead irrigation, and 40-50% greater than without irrigation. In the nonirrigated and overhead irrigated plots, concentrations of soluble salts, NO_3-N, K and Cl were greatest in the upper 0-5 cm of the plant bed, and were higher at the center than at the side. At the lower sampling depths, values were reduced, and did not vary with location. In the drip irrigated beds, concentrations were similar at all depths and locations and did not differ significantly from the lower values recorded for the overhead and nonirrigated plots. Throughout the season, soil moisture levels were highest with drip, intermediate with overhead and lowest with no irrigation. Maximum yields with drip irrigation were obtained with 34% as much water as was applied with overhead irrigation.

Mulched and nonmulched drip irrigated strawberry plants had significantly greater numbers of leaves and crowns·plants^{-1} as compared to unirrigated controls in a 2-year study on a sandy loam

soil (77). Leaf and crown dry weights were slightly greater at harvest due to irrigation. The number of flowers·plant^{-1} increased with irrigation in both years of the study while the numbers of fruit and yield·plant^{-1} were greater only in the first year (75).

Yield and number of fruit·ha^{-1} of zucchini squash were significantly higher with drip irrigation than without (9). Stem diameter increased and days to bloom after planting and percentage of cull fruit decreased in response to irrigation. The fruit produced with drip irrigation were of the highest quality. Similar findings were reported by Bhella (8) for muskmelon produced on silt loam and fine sandy loam soils. Drip irrigation significantly increased stem length and diameter and leaf area·plant^{-1} over nonirrigated plants. Early fruit yield, total yield and number of fruit·ha^{-1} were higher while the percentage of cull fruit at late harvest was reduced with drip as compared with the nonirrigated controls. However, the percentage soluble solids was significantly lower with irrigation than without.

The use of drip irrigation on sandy soils resulted in lower yields of mulched tomatoes than did use of seep irrigation in central Florida or overhead irrigation in north central Florida (72). The number of fruit·ha^{-1} responded in a similar manner. Average fruit size was largest with overhead irrigation, intermediate with drip and smallest with seep irrigation. Soluble salt concentrations in the upper 0-15 cm soil profile at the center of the bed and 15 cm to each side varied with fertilizer placement (73). However, except with the 100% banded treatment sampled in the fertilizer band, salt

concentrations were significantly lower with drip than with seep irrigation. When drip and overhead irrigation treatments were compared, soluble salt concentrations were lower with drip than with overhead irrigation with all fertilizer placements and at all bed locations. With all irrigation methods, root growth proliferated in the areas of fertilizer placement. With drip irrigation, root growth also was concentrated in the upper 5-6 cm of soil beneath the emitters while with overhead irrigation a circular mat of roots 10-12 cm in diameter developed around the stem of the plant. The authors concluded that the lower yields associated with drip irrigation were due to leaching of nutrients below the root zone, and that fertilizer placement and timing and rate of water application are more critical with drip than with other irrigation methods.

With all fertilizer applied in the irrigation water and with equal amounts of low salinity water applied to a sandy loam soil by each method, drip irrigated unmulched bell pepper plots outyielded furrow and sprinkler irrigated plots by 37 and 67%, respectively (7). Use of saline water reduced drip irrigated pepper yield by 14% but caused 54 and 94% yield reductions in furrow and sprinkler irrigated plots. Seasonal soil matric potentials averaged -23, -36 and -12 kPa for furrow, sprinkler and drip irrigated plots, respectively. In the 2nd year, water application was scheduled to maintain more uniform soil moisture. Yields were similar with all irrigation methods with nonsaline water but sprinkler irrigated plots received 25% more water and 30% more fertilizer than the drip irrigated plots, and the furrow irrigated plots 48% more water and

51% more fertilizer. Pepper yield was not affected by use of saline irrigation water with drip irrigation but was reduced 18 and 59% in furrow and sprinkler irrigated plots. At mid-season with both low and high saline water, soluble salt concentrations in the upper 0-2.5 cm soil profile were highest with drip, slightly lower with furrow and greatly reduced with sprinkler irrigation. Values decreased rapidly with increased depth and were similar at each depth with all methods. At the end of each season, soluble salt accumulation in the uppermost profile with use of low saline water was very high with furrow irrigation, significantly lower with drip and somewhat lower still with sprinkler irrigation. Concentrations decreased with increased depth with furrow and drip irrigation but were similar at all depths with sprinkler irrigation. When irrigated with saline water, soluble salts in the 0-2.5 cm depth were highest with furrow irrigation and greatly reduced with drip and sprinkler irrigation. At the greater depths sampled, salt concentrations decreased with all methods but were highest with sprinkler irrigation. The low yield and plant injury by sprinkler irrigation with saline water were attributed to osmotic shock caused by flushing salts which accumulated at the surface between irrigations into the root zone. With drip irrigation, salts accumulated in the soil surface midway between emitters and at the perimeter of the wetted zone.

Potato (Solanum tuberosum L.) yield with drip irrigation was 65% higher than with furrow irrigation (81). When water application with drip was reduced to 50% of that applied to the furrow irrigated

plots, yields were similar with each method. Use of saline water reduced drip irrigated potato yields by 21 and 48% in the 2 years of the study while tomato yields decreased 26%. The yield reduction in potatoes was due to a 22% decrease in the number of tubers and a 34% decrease in tuber size. The tomato yield decrease was caused by a 19% reduction in number of fruit. Size and quality of tomato fruit were not affected by use of saline water. After one season, soluble salt accumulation in the unmulched, drip irrigated plots was highest in the surface 0-20 cm depth of the loamy sand soil midway between the emitters and towards the margin of the wetted area. No salts were found in the zone below the emitters to a depth of 90 cm. With all fertilizer applied in equal quantities of saline water, yield of drip irrigated 'Moneymaker' tomatoes was more than double that obtained from overhead irrigated plots (38). When drip irrigated plants were partially irrigated by sprinkling with the saline water, leaves of cucumber and 'Marmande' tomato exhibited symptoms of salt toxicity, and no yields were produced. Sprinkling with saline water produced higher contents of soluble and diffusible ions, free ammonia and free amino acids in the leaves and reduced starch, protein, pigments and relative turgidity than drip irrigation alone. Pepper leaves also had higher contents of soluble and diffusible ions with overhead than with drip applied low saline water, but yields were not affected by irrigation method. The authors concluded that yield differences between drip and overhead irrigated crops when saline water is used are not due to soil water potentials alone but are partially attributable to salt injury to leaves. This is supported

by Doss et al. (24) who reported a higher percentage of defoliated tomato plants at the end of each of 3 seasons with overhead irrigation than with either furrow or drip irrigation.

Influence of Fertilizer Rate, Placement and Timing

With equal amounts of N as NH_4NO_3 applied preplant and at 2 and 4 weeks after transplanting, marketable head weight and total marketable yield of sprinkler irrigated broccoli increased linearly as N rate increased from 56 to 224 kg·ha^{-1} with plant populations ranging from 24,000 to 72,000 plants·ha^{-1}; highest yield was obtained with the highest N rate and population (25). Cull production on the loamy sand soil decreased linearly as N rate increased. On a fine sandy loam with 90 kg·ha^{-1} N broadcast preplant, and 0, 90 or 180 kg·ha^{-1} N as NH_4NO_3 top dressed 20 days after transplanting, yields of single harvest, unirrigated broccoli did not increase significantly above the 90 kg·ha^{-1} rate (22). Time to maturity was delayed by the top dressing but percent marketable heads increased. On a similar soil with all N broadcast before seeding, Hipp (42) obtained a significant increase in broccoli yield with N rates up to 168 kg·ha^{-1} with plant populations as high as 136,000 plants·ha^{-1}. Although the incidence of hollow stem increased with N rate, the increase in yield was greater than the loss due to hollow stems. With 1/3 of the fertilizer banded on the bed shoulder and the remainder of the 90, 180 and 270 kg·ha^{-1} N either applied as 2 equal side dressings 15 and 35 days after transplanting or injected weekly over a 6-week period in the furrow irrigation water, neither yield nor N recovery were

influenced by N application method (52). Plant and head weights increased with an increase in N rate on the loamy sand soil. In a 2nd study, N applied to the soil resulted in significantly higher broccoli yields than did injecting N in the irrigation water. Both yield and N recovery were higher with 225 than with 115 $kg \cdot ha^{-1}$ N.

Data from a 2-year study on the effects of various combinations of 5 levels each of N, P and K on yield of crookneck squash produced on a fine sand with overhead irrigation were used to formulate quadratic prediction equations with R^2 values of 0.94 and 0.89 (88). In both years, with NH_4NO_3 and KCl banded in 2 equal applications about 2 and 5 weeks after seeding, rate of N had the most significant effect on yields and plant growth. As application rates of all 3 nutrients increased, yields increased but at a decreasing rate. Maximum predicted yields occurred with N-K applied at 101-103 and 164-136 $kg \cdot ha^{-1}$. In 2 of 3 years, marketable yields of yellow summer squash were higher with 90 and 113 $kg \cdot ha^{-1}$ N as NH_4NO_3 applied in 5 equal weekly increments with overhead irrigation than with either 67.5 $kg \cdot ha^{-1}$ N applied similarly or 45 $kg \cdot ha^{-1}$ N applied preplant + 45 $kg \cdot ha^{-1}$ side-dressed 4 weeks after seeding (83). Highest yields were obtained with weekly applications of 22.5 $kg \cdot ha^{-1}$ N through the irrigation system for 5 weeks beginning 2 weeks after seeding.

With overhead irrigation and all fertilizer applied preplant, marketable yield and number of mulched, staked 'Walter' tomato fruit produced on a fine sand increased quadratically as N-K rate increased

from 101-112 to 303-336 kg·ha^{-1}, with the greater increase between 101-112 and 202-224 kg·ha^{-1} N-K (72). Both yield and fruit set were significantly lower with 100% of the N-K banded 7.6 cm to the side of the plant row and 7.6 cm below the soil surface than with 100% broadcast + incorporated, 10% broadcast + 90% surface banded, and 10% broadcast + 90% banded below the surface. Fruit size was not influenced by either N-K rate or placement. At the same location with 50% of the N-K applied by the 4 placement methods and the remainder injected in the irrigation water in 7 equal weekly applications, marketable yield, size and number of drip irrigated tomato fruit were not influenced by fertilizer placement. With similar soil and treatments at a 2nd location, yield and fruit set of drip irrigated tomatoes were highest with the banded below the surface and the broadcast + surface banded placements, intermediate with the broadcast + banded below the surface placement and lowest with the N-K broadcast + incorporated. Fruit were smallest with the broadcast treatment but were of similar size with the other placements. At both locations with drip irrigation, total marketable yield and size and number of fruit increased linearly with N-K rate. With seep irrigation at the 2nd location, N-K placement and rate did not affect marketable yield, size or number of fruit. On a fine loamy sand phase of a calcareous soil, complete or partial incorporation of fertilizers in mulched beds resulted in higher yields of overhead irrigated 'Fla. MH-1' tomatoes and 2nd crop squash than did banding on the top of the beds (14). Incorporation of

180-299 kg·ha^{-1} N-K resulted in similar tomato yields as banding 270-448 or 360-598 kg·ha^{-1} N-K. Residual soil N and K concentrations following tomato increased with an increase in rate of nutrient application and was highest at the 360-598 kg·ha^{-1} N-K rate; however, highest 2nd crop squash yield was obtained with 100% incorporation of N-K at the 270-448 kg·ha^{-1} rate. In a 2nd study, tomato yields were similar with 135-224 kg·ha^{-1} N-K incorporated and 270-448 kg·ha^{-1} N-K banded and were highest with 270-448 kg·ha^{-1} N-K incorporated in the bed. Yield of squash was not influenced by N-K rate but was significantly higher with the tomato fertilizer incorporated than banded. With 50% of the N-K incorporated preplant and the remainder added in 2 equal side dressings, highest yields of mulched 'Walter' tomatoes produced on a loamy sand with overhead irrigation were obtained with 60 kg·ha^{-1} N and 186 kg·ha^{-1} K (45). Increased N rate up to 168 kg·ha^{-1} did not increase yields but resulted in higher levels of soil NO_3-N to a 60 cm depth. A significant increase in yield and fruit size of seep irrigated, mulched, staked 'Walter' tomatoes occurred with rates above 242-278 kg·ha^{-1} N-K in only 1 of 4 seasons (29). The author concluded that 181 to 302 kg·ha^{-1} N and 209 to 348 kg·ha^{-1} K, with 10% broadcast and the remainder surface banded 24 cm to each side of the plant row are adequate for optimum production on an Immokalee fine sand. Others (20) reported that with similar placement, irrigation and soil type, yields of 'Flora-Dade' tomatoes were not influenced by rates above 148-171 kg·ha^{-1} N-K. Residual soluble salt concentrations to a 23 cm soil depth, however, increased as N-K application rate increased. On a fine loamy sand,

yields of unmulched, furrow irrigated 'Homestead 24' and 'Tropic' tomatoes were highest with N applied at 65 to 135 $kg \cdot ha^{-1}$ and supplemental irrigation to maintain 30% or more available water in the 0-60 cm soil depth (23). Additional increments of N or more frequent irrigation to maintain 70% available water did not increase yields. In both years of a 2-year study on a highly weathered oxisol, highest yields of drip irrigated unmulched pepper resulted with N-K applied weekly with the irrigation water in amounts adjusted to meet plant needs during the various growth periods (49). Applying similar total quantities with 1/2 banded to each side of the plant row before transplanting and the remainder side dressed later in the growing season, pepper yields were similar to those obtained with fertigation in a wet season, but were lower in a dry season. Lowest fruit yields were obtained with fertilizer broadcast on the plant bed surface in both years. Yield of drip irrigated muskmelon increased with rate when all N was applied continuously through the irrigation system but was highest with 40% broadcast preplant with the remainder injected (10). Stem growth and petiole NO_3-N concentration were not affected by rate with preplant + injection of N, but increased with rate when all N was injected in the irrigation water. With continuous injection in the irrigation water, total N applied in excess of 120 $kg \cdot ha^{-1}$ did not increase yields of drip irrigated tomatoes on a loam soil (86). Although the total amount of N removed from the soil by the crop increased as N application increased to 585 $kg \cdot ha^{-1}$, the additional N removed was partitioned into the vines and did not affect fruit N concentration or yield. Yields of 'Walter'

tomatoes produced with drip irrigation on 2 fine sandy soils were highest with 40% of the N-K and all P and micronutrients broadcast + incorporated into the beds and 60% of the N-K injected weekly than with 100% N-P-K and micronutrients broadcast + incorporated prior to transplanting (60). Levels of soil NO_3-N were higher with fertigation than with preplant timing. Leaf N concentrations were similar for early tissue samples but were higher with fertigation than with preplant NH_4NO_3 application later in the season. Leaf and immature fruit K concentrations were higher with the preplant KCl application than with fertigation. In a more recent study, Locascio et al. (62) obtained higher drip irrigated tomato yields at 2 of 3 locations with all fertilizer preplant incorporated than with 40% N-K and 100% P applied preplant and 60% N-K injected weekly. At the 3rd location, yields were similar with either application timing.

Successive Cropping with Polyethylene Mulch

Bryan and Dalton (14) successfully produced spring crops of plug-mix planted butternut squash on black and white-on-black plastic mulches with overhead irrigation, utilizing only residual nutrients from previous tomato crops. Surface broadcast and surface broadcast + incorporation of fall applied fertilizers produced the highest winter tomato and spring squash yields. Highest yields were obtained from both crops with the highest rate of fall fertilizer application. Residual N, P and K concentrations after tomato increased with an increase in application rate also. The concentration of nutrients remaining in the soil after harvesting

both crops, although lowest in plots where the fertilizer was broadcast + incorporated, was sufficient to produce a 3rd crop. Shaw et al. (80) developed a punch planter to place seed in polyethylene covered beds for double-cropping plastic mulch. Using only residual nutrients, yields of squash following tomato were equal to yields obtained with bare ground culture of squash with fertilizer applied at planting. In addition to saving fertilizer, cultivation and hoeing necessary for weed control in the unmulched plots were eliminated. Overhead irrigated sweet corn, yellow squash, cucumber and snap bean also have been produced as 2nd crops on plastic mulch following strawberries (4). Squash did not respond to supplemental fertilizer applied through holes in the plastic between the plants but corn, cucumber and snap bean yields were significantly higher with 2nd crop fertilization than with residual nutrients. All crop yields were within the range of state averages and were produced without the added expense of fumigation, bed preparation and mulching. Everett (30) planted tomatoes and cucumber as 2nd crops following unstaked tomatoes on plastic mulch with seep irrigation. The 2nd crops were fertilized through holes made in the plastic near each plant. Second crop yields with residual fertilizer averaged 12.1 and 23.9 $t \cdot ha^{-1}$ for tomatoes and cucumbers, respectively. Yields increased significantly with addition of fertilizer, to 19.8 and 46.4 $t \cdot ha^{-1}$ for tomatoes and cucumbers but rate of 2nd crop fertilization did not affect yields. Tomato fruit size, however, was larger with the 2 higher rates. Placement of 2nd crop fertilizer, either 20 cm to one side of the plant, 20 cm to both sides, or midway

between plants, did not influence yields or fruit size of either crop. It was estimated that 2nd crop tomato production costs were 70-75% lower than for the first crop of ground tomatoes. Hayslip et al. (41) used a tractor mounted square-bar applicator to apply fumigant and liquid fertilizer in established mulched tomato beds. Sweet corn yields from plots receiving liquid fertilizer increased 126% over nonfertilized residual check plots. In the same study, a modified plug-mix planter was used to apply dry fertilizer through the 0.1 mm thick plastic mulch for a 2nd crop of staked tomatoes. Fertilized plots yielded 73.2 $t \cdot ha^{-1}$ of marketable fruit while only 41 $t \cdot ha^{-1}$ were produced with residual nutrients. Size of early fruit was larger with 2nd crop fertilization. Successive 3rd crops of unpruned, unstaked tomatoes and cucumbers were produced on the same beds used for the 2nd crop tomatoes. Third crop tomatoes were planted in plots to which no 2nd crop fertilizer had been added while cucumbers were seeded into plots which had been refertilized for the 2nd crop. All plots were refertilized with the modified plug-mix planter for the 3rd crop. Yields of 67.1 and 40.4 $t \cdot ha^{-1}$ were obtained from 3rd crop cucumber and tomato, respectively. A liquid fertilizer injection wheel was used to fertilize 2nd crop spring planted zucchini squash and muskmelon following fall tomato production (20). Yields of both crops were lowest with residual fertilizer, increased with increasing rates of supplemental injected nutrients, and were highest with split applications as compared to a single preplant application. With pepper and squash grown in succession in undisturbed beds using drip irrigation to supply most

first crop nutrients and all 2nd crop nutrients, highest yields of both crops were obtained from aluminum-coated film mulched plots with and without fumigation, followed by unmulched fumigated plots, and unmulched, unfumigated control plots (48). Second crop squash yields were reduced by root knot nematode infestation in the unmulched plots. Jaworski et al. (44) previously reported that polyethylene mulch and fertilization with drip irrigation can result in acceptable vegetable yields even with suboptimal control of some soil pests. An abundant root system concentrated near the soil surface under the drip emitter was sufficient to overcome stress induced by soil pathogens so long as adequate moisture and nutrients were applied in the drip system.

Brown et al. (12) compared the economic returns for vegetables produced in monoculture or double-crop systems. Highest net returns were obtained with squash monocropped and squash/broccoli double-cropped, followed by squash double-cropped, and cauliflower and cauliflower/snap bean double-cropped. Lowest economic returns were obtained with monocropped broccoli, cauliflower, snap bean and sweet corn. Incomplete time for complete harvest of some crops due to the short growing season at the northern location reduced returns to some double-cropping sequences.

CHAPTER 3
MATERIALS AND METHODS

Field experiments were conducted in 1983 and 1984 at the IFAS Horticultural Unit, Gainesville, Fl., and the AREC, Quincy, Fl., to examine the influence of irrigation method, rate and time of N-K application and crop sequence on yield and nutrient composition of several vegetable crops and on soil chemical characteristics.

The experimental design for the 1983 broccoli crop was a split-split plot with 8 replications. Main plots were 2 locations, Gainesville and Quincy, Fl., subplot treatments were overhead and drip irrigation and sub-subplot treatments were 2 N-K rates (Table 3-1). In the spring of 1984, the 1983 broccoli plots were subdivided, and tomato and squash crops were grown in a split-split plot design experiment with 4 replications. Treatments were identical to those applied to the previous broccoli crop, with one-half of the N-K rate plots grown with residual (fall + fall) fertilization and the other half refertilized (fall + spring) prior to crop establishment. The subsequent 1984 broccoli crop experimental design was similar (split-split plot with 4 replications); however, the effect of the preceding tomato or squash crop on broccoli yield, mineral composition and soil characteristics was examined as an additional experimental factor.

Table 3-1. Treatments in successive vegetable cropping field experiment.

Main Plots	Sub-subplots
Location	N-K rate ($kg \cdot ha^{-1}$)
Gainesville	135-202
Quincy	270-404
Subplots	Application time
Irrigation method	Fall + fall
Overhead	Fall + spring
Drip	Crop sequence
	Broccoli-tomato-broccoli (Br-Tm-Br)
	Broccoli-squash-broccoli (Br-Sq-Br)

The soil at the Gainesville site was an Arredondo fine sand (loamy, siliceous, hyperthermic grossarenic palendult) and at Quincy the soil was a Ruston loamy fine sand (fine-loamy, siliceous thermic typic palendult). Soil chemical characteristics prior to treatment application are shown in Table 3-2.

Dolomitic lime was applied at rates of 2.24 and 4.48 $t \cdot ha^{-1}$ at Gainesville and Quincy, respectively. Nitrogen (33.6 $kg \cdot ha^{-1}$) as NH_4NO_3 was broadcast and grain sorghum (Sorghum vulgare Pers. 'Colt') was drilled at 9 $kg \cdot ha^{-1}$. The cover crop was turned under and disced several times prior to plot established in the fall of 1983.

Plant beds 18.2 m long and 1.8 m apart were formed with a 1 m wide bed press and fertilizer was broadcast by hand on top of the formed beds. Plots received 112 $kg \cdot ha^{-1}$ P as triple super phosphate and 33.6 $kg \cdot ha^{-1}$ FN503 (Frit Industries, Ozark, Al.) micronutrient combination.

At bedding, overhead irrigated plots received 100% of the treatment N-K as NH_4NO_3 and KCl but 40% was applied to the drip irrigated treatments, with the remaining 60% applied weekly through the drip irrigation system (Table 3-3). In a once-over operation, a single 0.38 mm thick biwall (Anjac) drip irrigation line (3.35 $l \cdot hr^{-1} \cdot m^{-1}$ at 51.6 Pa) with emitters spaced 30 cm apart was centered under 0.064 mm thick black polyethylene mulch. At the same time, fertilizer was rototilled into the top 15 cm of the raised bed and methylbromide-chloropicrin (450 and 500 $kg \cdot ha^{-1}$ at Gainesville and Quincy) injected. On 26 Sept. 1983, 6-week old 'Emperor'

Table 3-2. Soil chemical characteristics at Gainesville and Quincy, Fl.

Location	pH	EC[z] ($dS \cdot m^{-1}$)	Soil concn (ppm)					
			NO_3-N	NH_4-N	P	K	Ca	Mg
Gainesville[y]	6.74	0.65	0.88	1.33	1.08	4.90	10.3	1.60
Quincy[x,w]	5.50	-	-	-	320	140	320	80

[z] EC reported on a saturated paste extract basis.
[y] Gainesville soil extraction method--1:1 soil:water.
[x] Quincy soil extraction method--Mehlich I.
[w] Before addition of 4.48 $t \cdot ha^{-1}$ dolomitic lime.

Table 3-3. Weekly percentage of N-K applied through drip irrigation.

Time (week)[z]	Broccoli	Tomato-squash
	%	
1	5	5
2	10	5
3	15	10
4	15	10
5	15	15
6	15	15
7	10	10
8	10	10
9	5	5
10	-	5
11	-	5
12	-	5

[z] Weeks after transplanting or emergence of crop.

broccoli transplants were set 30 cm apart, 60 cm between rows, 2 rows·bed^{-1} (36,000 plants·ha^{-1}) at both locations.

Overhead irrigation was applied 2 to 3 times weekly at a rate equal to 1X pan evaporation (ET_{pan}) as measured with a U.S. Weather Bureau class A evaporation pan at each site (Table 3-4). Drip irrigation was applied daily at a rate of 0.55X ET_{pan} for the entire plot area based on the average ET_{pan} for the previous 10 day period. (The mulched, raised bed area received water at a rate equal to 1X ET_{pan}.) The quantity of water applied was reduced to compensate for rainfall which occurred since the previous irrigation application. Recommended commercial broccoli production practices were followed (69).

Broccoli heads from the interior 15 m of each plot were harvested 5 times over a 3-week period at each location and the number and weight of marketable central heads 20 cm in length and 6.4 cm in diameter (minimum) were recorded (1).

Twelve recently matured broccoli leaves·plot^{-1} were sampled at 4 and 9 weeks after transplanting. A composite sample of 8 heads·plot^{-1} was collected at the first harvest (9 weeks after transplanting) and the above ground portions of 4 plants without heads (plant sample) were collected from each plot after the final harvest. Tissue samples were dried in a forced draft oven at 65`C for 72 hours and ground in a Wiley mill to pass a 40-mesh screen (63). One-gram subsamples were ashed at 500`C for 8-10 hours, solubilized in 1 N HCl, filtered and brought to 50 ml volume of filtrate. Phosphorus concentrations were determined with a Technicon

Table 3-4. Monthly evaporation (ET_{pan}) and rainfall totals for Gainesville and Quincy, Fl.

Month	Gainesville		Quincy	
	ET_{pan}	Rainfall	ET_{pan}	Rainfall
09-83	10.4[z]	27.8[z]	12.5	9.3
10-83	10.4	5.4	10.5	3.7
11-83	6.6	15.0	5.6	15.0
12-83	4.4	6.2	4.1	16.1
01-84	7.2	3.0	4.7	9.6
02-84	10.1	12.1	6.5	17.3
03-84	12.9	8.1	14.6	25.2
04-84	12.6	10.7	13.1	18.6
05-84	17.9	21.2	16.7	15.4
06-84	18.1	4.9	16.9	16.7
07-84	14.9	5.2	13.0	26.8
08-84	17.1	8.5	11.9	10.9
09-84	13.9	6.1	15.6	4.3
10-84	12.5	1.7	13.4	9.2
11-84	8.1	5.6	7.9	5.4
12-84	6.3	1.1	5.5	2.4

[z] Values in cm.

AutoAnalyzer and K, Ca and Mg by atomic absorption spectroscopy by the IFAS Extension Soil Testing and Analytical Laboratory, Gainesville, Fl. After overnight digestion of 0.2 g tissue subsamples, total N was determined by micro-Kjeldahl procedure according to the method of Nelson and Sommers (68) as modified (35).

Composite soil samples from 3 locations in each plot were taken after the final harvest of all crops at the center and side (35 cm from center) of the bed at 0-10, 10-20 and 20-30 cm soil depths. Soil was dried at 65`C for 72 hours. Seventy-gram subsamples were combined with 70 ml distilled water, stirred, and allowed to stand for 30 minutes (43). The resultant slurry was filtered through No. 4 Whatman filter paper, and 25 ml aliquots were analyzed by the IFAS Extension Soil Testing and Analytical Laboratory for NO_3-N, NH_4-N and P with a Technicon AutoAnalyzer and for K, Ca and Mg concentrations by atomic absorption spectroscopy. Solution pH and electrical conductivity (EC) were determined with an Orion Research Model 701 digital pH meter and an Industrial Instruments Solu-Bridge.

After field sampling was completed, plant residues were removed. In Mar. 1984, row middles were cultivated for weed control. Fall + spring fertilized, overhead irrigated plots received 135-202 or 270-404 $kg \cdot ha^{-1}$ N-K as NH_4NO_3 and KCl applied through holes made 30 cm apart in the center of the bed. The same nutrient rates were applied through the irrigation system to the drip irrigated plots over a 12 week period (Table 3-3). Fall + fall fertilized plots received water only.

The 18.2 m broccoli plots were divided to accommodate 2 different subsequent crops, squash and tomato. 'Dixie' summer squash was direct seeded by hand into the holes used for the 1983 broccoli crop (30x45 cm spacing) on 15 Mar. 1984, and 2 Apr. 1984, at Gainesville and Quincy, respectively, and thinned to 36,000 plants·ha^{-1} one week after emergence. Irrigation was scheduled as previously discussed, and pest control was accomplished according to recommended commercial practices (66). Squash was harvested from the interior 7 m of each 9.1 m plot every 2-3 days beginning 6 weeks after emergence and continuing for 5 weeks. The number and weight of marketable fruit were recorded, and 6 fruit·plot^{-1} were sampled at the first and last harvest for mineral analyses (2). Six recently matured leaves and the above ground portion of 2 plants·plot^{-1} were collected 6 and 11 weeks after emergence for analyses. Plant tissue and soil samples were processed as previously described.

One-month old 'Sunny' tomato plants were set 45 cm apart, 15 cm from the bed center, in a single row in each 9.1 m plot (11,800 plants·ha^{-1}) on 22 Mar. 1984, at Gainesville and 2 Apr. 1984, at Quincy. Irrigation was scheduled as previously discussed and cultural practices were according to recommended commercial practices (65). Harvest of the pruned, staked tomato crop began 12 weeks after transplanting and continued for 5 weeks. Six harvests were conducted at Gainesville and 3 at Quincy. The number, weight and size of marketable fruit and the number and weight of cull fruit were recorded at Gainesville while the number and weight of marketable and cull fruit were recorded at Quincy (3). Recently matured leaves were

taken 7 and 14 weeks after transplanting, 6 fruit·plot^{-1} were sampled 14 weeks after transplanting, and the above ground portion of 2 plants·plot^{-1} were collected after the final harvest. One-quarter of each of the 6 fruit were combined and macerated in a Waring blender before drying for mineral analyses. Plant tissue and soil analyses were conducted as previously discussed.

Soil samples from 3 locations·plot^{-1} were taken daily for 3 days at the center and side of the bed at 0-10, 10-20 and 20-30 cm soil depths, from overhead and drip irrigated tomato plots receiving fall + spring N-K at 270-404 kg·ha^{-1}. Drip irrigated plots received 6.1 mm water daily, after samples were taken (Table 3-5). After the first sample (7 July 1984), 15.2 mm of water was applied to the overhead irrigated plots. Samples were weighed, dried at 65°C in a forced draft oven for 96 hours, reweighed, and soil moisture percentage calculated. Data were analyzed as a split plot design with 4 replications to determine the influence of irrigation method on soil moisture at the locations and depths sampled.

After all field sampling was completed, crop residues were removed and row middles cultivated. Fall + fall fertilized overhead irrigated plots received 135-202 and 270-404 kg·ha^{-1} N-K as NH_4NO_3 and KCl as described previously for the spring crops. Drip irrigated, fall + fall fertilized plots received the same nutrients over a 9-week period in weekly applications with the irrigation water (Table 3-3).

One-month old 'Emperor' broccoli plants were set in the field on 14 Sept. 1984, in the same holes used for the previous fall broccoli

Table 3-5. Daily evaporation (ET_{pan}), rainfall and irrigation applications at Gainesville, Fl., 1984.

Date	ET_{pan}[z]	Rainfall	Irrigation		Cumulative Balance[y]	
			Overhead	Drip	Overhead	Drip
06-30	5.8[x]	25.4	0	0	0	0
07-01	1.8	25.4	0	0	0	0
07-02	3.8	0	0	0	-3.8	-3.8
07-03	5.6	0	0	0	-9.4	-9.4
07-04	3.8	0	0	6.1	-13.2	-7.1
07-05	5.6	0	15.2	6.1	-3.6	-6.6
07-06	7.4	0	0	6.1	-11.0	-7.9
07-07[w]	7.6	0	15.2	6.1	-3.4	-9.4
07-08	8.4	0	0	6.1	-11.8	-11.7
07-09	5.6	19.1	15.2	7.6	0	0

[z] ET_{pan} measured with standard U.S. Weather Bureau class A evaporation pan.

[y] Cumulative balance = ET_{pan} - precipitation - irrigation.

[x] Values in mm.

[w] Samples taken daily prior to irrigation or precipitation.

crop. Unseasonal temperatures at Quincy reduced broccoli plant stands. Sufficient plants were not available to replace all the plants lost to heat stress, so only 3 replications were used in this portion of the field trials. Recommended commercial broccoli production practices were followed.

Marketable central heads were harvested 5 times at Gainesville and 6 times at Quincy over a 4-week period beginning 11 Nov. 1984, from the interior 7 m of each plot. Six recently matured leaves·plot^{-1} were collected 6 weeks after transplanting, and 4 heads·plot^{-1} were sampled 4 weeks later. The remaining above ground portions of 2 plants·plot^{-1} were collected after the final harvest 12 weeks after transplanting. Soil samples were taken, and soil and tissue samples were prepared and analyzed as previously discussed.

Data were subjected to analysis of variance using computerized programs (78). Regression analysis conducted to test for significant linear or quadratic effects of depth were based on single degrees of freedom of orthogonal comparisons.

CHAPTER 4
RESULTS

1983 Broccoli Field Experiment

Yield

Early broccoli yield was higher at Quincy than Gainesville and with drip than with overhead irrigation, but was not affected by N-K rate (Table 4-1). Late broccoli yield was not influenced by location or irrigation method but increased with an increase in N-K rate. Higher total yields were obtained with drip than with overhead irrigation, with the higher N-K rate and at the Quincy location. The number of heads$\cdot$ha^{-1} was higher at Gainesville than at Quincy and with drip than with overhead irrigation. Irrigation method and location interacted in their effect on number of heads produced (Table 4-2). The number of heads$\cdot$ha^{-1} was higher at Gainesville with drip than with overhead irrigation but was not affected by irrigation method at Quincy. Fertilization rate had no effect on number or average weight of broccoli heads (Table 4-1). Average head weight was higher at Quincy than at Gainesville but was not affected by irrigation method.

Tissue Analyses

Early leaf (30 days after transplanting) tissue N concentration was higher with Quincy than Gainesville samples but was not affected by location for other plant tissues (Table 4-3). The N concentration of leaves taken at 60 days after transplanting (leaf 2) was higher

Table 4-1. Marketable yield of broccoli as affected by location, irrigation method and N-K rate, 1983.

Treatment	Yield ($t \cdot ha^{-1}$)			Head	
	Early	Late	Total	No. ($1000 \cdot ha^{-1}$)	Wt (g)
Location (L)					
Gainesville	2.7	3.5	6.2	26.6	235
Quincy	4.2	3.8	8.0	25.0	319
Significance[z]	**	NS	**	*	***
Irrigation (I)					
Overhead	2.7	3.8	6.5	24.1	269
Drip	4.2	3.5	7.7	27.6	284
Significance	***	NS	***	***	NS
LxI	NS	NS	NS	**	NS
N-K rate ($kg \cdot ha^{-1}$)					
135-202	3.6	3.3	6.9	26.2	264
270-404	3.3	4.1	7.4	25.4	290
Significance	NS	***	**	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-2. Number of broccoli heads as affected by location x irrigation method interaction.

Irrigation	No. ($1000 \cdot ha^{-1}$)	
	Gainesville	Quincy
Overhead	23.4	24.7
Drip	29.8	25.3
	***[z]	NS

[z] Effects were not significant (NS) or significant at the 0.1% (***) level.

Table 4-3. Nitrogen concentration of broccoli as affected by location, irrigation method and N-K rate, 1983.

Treatment	N concn (%)			
	Leaf 1[z]	Leaf 2	Head	Plant
Location (L)				
Gainesville	5.78	5.53	5.24	3.12
Quincy	6.36	5.64	5.29	3.26
Significance[y]	**	NS	NS	NS
Irrigation (I)				
Overhead	5.99	5.44	5.15	3.31
Drip	6.14	5.74	5.38	3.07
Significance	NS	*	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	5.94	5.14	4.95	2.81
270-404	6.19	6.03	5.58	3.57
Significance	**	***	***	***
LxR	NS	*	NS	NS
IxR	NS	*	NS	NS

[z] Leaf 1 and 2 samples taken at 30 and 60 days after transplanting.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

with drip than overhead irrigation. Tissue N concentrations were similar for all other tissue with both irrigation methods. Total N concentration in all tissue was higher with 270-404 $kg \cdot ha^{-1}$ N-K than with the 135-202 rate. However, significant interactions occurred between N-K rate x location and N-K rate x irrigation method at the time of the second leaf sampling (Table 4-4). The rate of increase of tissue N with an increase in N-K rate was greater at Gainesville than at Quincy. Leaf N concentration increased with N-K rate with both irrigation methods. With the lower N-K rate, irrigation method had no effect on leaf N concentration but with the higher nutrient rate, N concentration was higher with drip than with overhead irrigation.

Leaf 2 and plant P concentrations were higher at Gainesville than Quincy (Table 4-5). Concentrations of P in the first leaf and head samples were not affected by location, but were higher with drip than with overhead irrigation. Irrigation method did not influence P concentration of leaves taken at the 2nd sampling or whole plant tissue. Tissue P concentration was not affected by N-K rate at the earliest sampling time but increased with N-K rate at all later times. The P concentration of broccoli heads was influenced by an interaction between location and N-K rate (Table 4-6). At Gainesville, head P concentration increased with N-K rate but at Quincy, N-K rate had no effect.

Thirty days after transplanting, leaf K concentration was higher at Quincy than at Gainesville but the K concentrations of leaf and head samples taken 60 days after transplanting were similar at both locations (Table 4-7). Whole plant K concentration was higher at

Table 4-4. Leaf N concentration 60 days after transplanting as affected by N-K rate x location and N-K rate x irrigation method interactions.

N-K rate ($kg \cdot ha^{-1}$)	N concn (%)			
	Location		Irrigation	
	Gainesville	Quincy	Overhead	Drip
135-202	4.98	5.31	5.11	5.18NS[z]
270-404	6.08	5.97	5.76	6.29***
	***	***	***	***

[z] Effects were not significant (NS) or significant at the 0.1% (***) level.

Table 4-5. Phosphorus concentration of broccoli as affected by location, irrigation method and N-K rate, 1983.

Treatment	P concn (%)			
	Leaf 1[z]	Leaf 2	Head	Plant
Location (L)				
Gainesville	0.34	0.49	0.90	0.67
Quincy	0.35	0.38	0.82	0.50
Significance[y]	NS	*	NS	**
Irrigation				
Overhead	0.32	0.42	0.83	0.56
Drip	0.37	0.44	0.89	0.60
Significance	**	NS	*	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	0.33	0.41	0.85	0.56
270-404	0.35	0.45	0.87	0.60
Significance	NS	**	*	*
LxR	NS	NS	*	NS

[z] Leaf 1 and 2 samples taken at 30 and 60 days after transplanting.
[y] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-6. Broccoli head P concentration as affected by location x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	P concn (%)	
	Gainesville	Quincy
135-202	0.88	0.82
270-404	0.93	0.82
	*[z]	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-7. Potassium concentration of broccoli as affected by location, irrigation method and N-K rate, 1983.

Treatment	K concn (%)			
	Leaf 1[z]	Leaf 2	Head	Plant
Location				
Gainesville	2.77	2.75	4.24	3.98
Quincy	3.08	2.23	4.16	3.49
Significance[y]	**	NS	NS	*
Irrigation (I)				
Overhead	3.03	2.55	4.27	3.93
Drip	2.82	2.43	4.13	3.54
Significance	NS	NS	NS	*
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	2.82	2.34	4.20	3.44
270-404	3.03	2.64	4.20	4.03
Significance	**	***	NS	***
IxR	NS	NS	NS	**

[z] Leaf 1 and 2 samples taken at 30 and 60 days after transplanting.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Gainesville than at Quincy. Tissue K concentrations of both leaf and head samples were not affected by irrigation method, but 75 days after transplanting, whole plant K concentration was higher with overhead than with drip irrigation. Concentration of K increased with N-K rate in all leaf and whole plant tissues but was not affected by N-K rate in the broccoli head tissue. Irrigation method and N-K rate interacted in their effect on whole plant K concentration (Table 4-8). With the lower N-K rate, plant K concentration was higher with overhead than with drip irrigation but with the higher rate, K concentration was similar with both irrigation methods.

Concentration of leaf Ca 30 days after transplanting was higher at Gainesville than at Quincy (Table 4-9). However, leaf Ca concentration 60 days after transplanting was higher at Quincy than at Gainesville. Head and plant Ca concentrations were similar at both locations. Broccoli head Ca concentration was higher with overhead than with drip irrigation but irrigation method did not affect tissue Ca concentration in the other samples. Plant Ca concentration increased with N-K rate but N-K rate did not influence Ca concentration in leaf or head tissues. Location, irrigation method and N-K rate interacted in their effect on leaf Ca concentration 60 days after transplanting (Table 4-10). At both Gainesville and Quincy, 2nd leaf Ca concentration was not affected by N-K rate with overhead irrigation but increased with an increase in N-K rate with drip irrigation at Gainesville and decreased at Quincy.

The Mg concentration in all tissue samples was higher at Quincy than at Gainesville (Table 4-11). Thirty days after transplanting,

Table 4-8. Broccoli plant K concentration as affected by irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	K conc (%)	
	Overhead	Drip
135-202	3.76	3.11***[z]
270-404	4.09	3.96NS
	*	***

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-9. Calcium concentration of broccoli as affected by location, irrigation method and N-K rate, 1983.

Treatment	Ca conc (%)			
	Leaf 1[z]	Leaf 2	Head	Plant
Location (L)				
Gainesville	3.70	2.55	0.49	2.63
Quincy	3.00	2.89	0.53	2.12
Significance[y]	**	*	NS	NS
Irrigation (I)				
Overhead	3.30	2.75	0.54	2.50
Drip	3.40	2.70	0.48	2.26
Significance	NS	NS	***	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	3.42	2.75	0.51	2.28
270-404	3.28	2.70	0.51	2.47
Significance	NS	NS	NS	***
LxIxR	NS	*	NS	NS

[z] Leaf 1 and 2 samples taken at 30 and 60 days after transplanting.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-10. Leaf Ca concentration 60 days after transplanting as affected by location x irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Overhead	Drip	Overhead	Drip
		Ca concn (%)		
135-202	2.54	2.37NS[z]	3.03	3.05NS
270-404	2.52	2.79NS	2.91	2.57*
	NS	*	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-11. Magnesium concentration of broccoli as affected by location, irrigation method and N-K rate, 1983.

Treatment	Mg concn (%)			
	Leaf 1[z]	Leaf 2	Head	Plant
Location (L)				
Gainesville	0.39	0.29	0.26	0.33
Quincy	0.76	0.56	0.29	0.52
Significance[y]	***	***	*	*
Irrigation				
Overhead	0.60	0.45	0.28	0.46
Drip	0.55	0.40	0.27	0.39
Significance	NS	*	*	*
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	0.60	0.43	0.28	0.41
270-404	0.55	0.41	0.27	0.44
Significance	***	NS	NS	*
LxR	NS	**	NS	NS

[z] Leaf 1 and 2 samples taken at 30 and 60 days after transplanting.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

leaf Mg concentration was not affected by irrigation method but in later leaf, head and plant samples, Mg concentration was higher with overhead than with drip irrigation. Tissue Mg concentration decreased with an increase in N-K rate in the early leaf sample, was not influenced by N-K rate in the later leaf and head samples, and increased with N-K rate in the plant sample. However, leaf Mg 60 days after transplanting was influenced by an interaction between location and N-K rate (Table 4-12). At Gainesville, leaf Mg concentration was not affected by N-K rate, but at Quincy tissue Mg concentration decreased with an increase in N-K rate.

Head dry matter percentage and plant dry weight were not affected by location or irrigation method (Table 4-13). Head dry matter percentage was lower with the higher of the 2 N-K rates. Plant dry weight was not influenced by N-K rate but irrigation method and N-K rate interacted in their effect on dry weight (Table 4-14). With overhead irrigation, plant dry weight was not affected by N-K rate, but with drip irrigation, plant dry weight increased with an increase in N-K rate.

Gainesville Soil Analyses

At Gainesville, soil pH decreased with an increase in N-K rate (Table 4-15). Irrigation method and bed location did not affect pH but N-K rate interacted with both variables (Table 4-16). At the side of the bed with drip irrigation, the pH was higher with the lower than higher N-K rate. At the bed center with drip and at both bed locations with overhead irrigation, N-K rate did not influence soil pH. Soil pH values were similar at all depths (Table 4-15).

Table 4-12. Leaf Mg concentration 60 days after transplanting as affected by location x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Mg conen (%)	
	Gainesville	Quincy
135-202	0.28	0.58
270-404	0.30	0.53
	NS[z]	*

[z] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-13. Broccoli head dry matter percent and plant dry matter accumulation as affected by location, irrigation method and N-K rate, 1983.

Treatment	Head dry matter (%)	Plant dry wt (g)
Location		
Gainesville	8.07	61.4
Quincy	8.03	72.6
Significance[z]	NS	NS
Irrigation (I)		
Overhead	8.09	63.2
Drip	8.01	70.7
Significance	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)		
135-202	8.26	65.6
270-404	7.84	68.4
Significance	***	NS
IxR	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-14. Broccoli plant dry weight as affected by irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Dry wt (g)	
	Overhead	Drip
135-202	66.4	64.7NS[z]
270-404	60.1	76.7**
	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-15. Soil chemical characteristics after broccoli at Gainesville as affected by irrigation method, N-K rate, bed location and soil depth, 1983.

Treatment	pH	EC ($dS \cdot m^{-1}$)	Soil concn (ppm)					
			NO_3-N	NH_4-N	P	K	Ca	Mg
Irrigation (I)								
Overhead	6.33	2.61	18.3	8.81	0.61	35.9	29.0	4.69
Drip	6.36	1.14	2.15	0.71	1.03	14.5	13.0	2.37
Significance[z]	NS	*	NS	NS	*	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)								
135-202	6.37	1.31	6.48	2.54	0.87	13.1	17.4	3.15
270-404	6.32	2.43	13.9	6.98	0.76	37.4	24.6	3.91
Significance	**	***	**	*	NS	***	***	*
IxR	***	*	NS	*	NS	*	**	NS
Location (L)								
Center	6.35	2.55	14.6	8.22	0.92	38.0	25.9	4.28
Side	6.34	1.20	5.77	1.30	0.72	12.4	16.0	2.79
Significance	NS	***	***	***	**	***	***	***
IxL	NS	***	**	***	***	***	***	***
RxL	NS	NS	*	NS	NS	**	NS	NS
IxRxL	*	*	**	NS	NS	NS	NS	NS
Depth (D) (cm)								
0-10	6.35	3.16	18.0	11.1	1.11	48.5	34.0	5.59
10-20	6.38	1.55	8.38	2.37	0.76	18.2	18.4	2.95
20-30	6.32	0.91	4.20	0.79	0.58	8.90	10.5	2.05
Significance	NS	***	***	***	L***	***	***	***
LxD	NS	***	*	**	L**	***	***	**
IxLxD	NS	***	*	**	NS	***	***	***
RxD	NS	L*	NS	NS	NS	**	NS	NS
IxRxD	NS	NS	NS	NS	NS	*	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L).

Table 4-16. Soil pH, EC and NO_3-N concentration as affected by irrigation method x N-K rate x bed location interactions.

Location and N-K rate ($kg \cdot ha^{-1}$)	pH		EC ($dS \cdot m^{-1}$)		NO_3-N (ppm)	
	Overhead	Drip	Overhead	Drip	Overhead	Drip
Center						
135-202	6.35	6.40NS[z]	2.77	0.88**	14.6	1.86**
270-404	6.33	6.32NS	5.10	1.44***	39.5	2.60***
	NS	NS	*	***	*	NS
Side						
135-202	6.30	6.45***	0.85	0.74NS	9.18	0.29NS
270-404	6.35	6.27NS	1.70	1.50NS	9.73	3.87NS
	NS	***	***	***	NS	***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Soil EC was higher with overhead than with drip irrigation and increased with N-K rate (Table 4-15). Soil EC was higher at the center than at the side of the bed but location, irrigation method and N-K rate interacted in their effects on conductivity (Table 4-16). At the center of the bed with both N-K rates, higher EC values were obtained with overhead than with drip irrigation but at the side of the bed, EC values were similar with both irrigation methods and N-K rates. Although EC differed with depth of soil, significant interactions occurred between depth and the other variables (Table 4-17). Soil EC decreased linearly with an increase in soil depth at the center of the bed with overhead irrigation and at the side of the bed with drip irrigation. At the side of the bed with overhead irrigation and at the center with drip, EC values were similar at all depths. Soil EC increased with N-K rate at all depths (Table 4-18). With each N-K rate, soil EC decreased significantly from 0-10 to 10-20 cm, then decreased slightly from the 10-20 to the 20-30 cm depth.

Soil NO_3-N concentration was not affected by irrigation method but increased with N-K rate and was higher at the center than at the side of the bed (Table 4-15). However, these variables interacted in their effect on NO_3-N concentration (Table 4-16). At the center of the bed with overhead irrigation and at the side with drip irrigation, sample NO_3-N values increased with N-K rate. At the bed center with drip irrigation and at the side with overhead, NO_3-N concentration was not affected by N-K rate. As depth increased, NO_3-N concentration decreased but irrigation method, N-K rate and depth interacted in

Table 4-17. Soil EC and NO_3-N, NH_4-N, K, Ca and Mg concentrations as affected by irrigation method x bed location x soil depth interaction.

Irrigation, location and depth (cm)	EC ($dS \cdot m^{-1}$)	Soil conen (ppm) NO_3-N	NH_4-N	K	Ca	Mg
Overhead						
Center						
0-10	7.69	52.2	38.7	126	76.4	12.2
10-20	3.07	21.6	7.73	32.1	36.4	5.32
20-30	1.05	7.30	1.02	7.96	12.8	2.53
	L***[z]	L***	L***	L***Q*	L***	L***
Side						
0-10	2.15	15.0	4.28	33.1	25.1	4.05
10-20	0.94	6.55	0.63	9.74	14.0	2.29
20-30	0.73	6.85	0.48	6.00	9.08	1.73
	NS	NS	NS	NS	L*	NS
Drip						
Center						
0-10	1.29	1.59	0.76	22.9	11.3	2.12
10-20	1.19	3.82	0.73	23.9	9.44	1.73
20-30	0.99	1.29	0.36	14.9	9.20	1.75
	NS	NS	NS	NS	NS	NS
Side						
0-10	1.53	3.34	0.75	11.7	23.4	3.96
10-20	0.98	1.53	0.38	7.23	13.9	2.49
20-30	0.84	1.37	1.31	6.52	10.8	2.18
	L**	NS	NS	NS	L***	L***

[z] Effects were not significant (NS) or linear (L) or quadratic (Q) at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-18. Soil EC as affected by N-K rate x soil depth interaction.

Depth (cm)	EC ($dS \cdot m^{-1}$) 135-202	270-404
0-10	2.26	4.07*[z]
10-20	0.92	2.17*
20-30	0.75	1.07**
	L**Q*	L***Q***

[z] Effects were significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

their effect on NO_3-N concentration (Table 4-17). At the center of the bed with overhead irrigation, NO_3-N concentration decreased linearly with increased depth. With drip irrigation at the center and at the side with either irrigation method, the concentration of NO_3-N was similar at all depths.

The concentration of NH_4-N was not influenced by irrigation method but increased with N-K rate (Table 4-15). However, irrigation method and N-K rate interacted in their effect on NH_4-N concentration (Table 4-19). The NH_4-N concentration was much higher with overhead than with drip irrigation with the higher than the lower N-K rate. Soil NH_4-N concentration was higher at the center of the bed than at the side and decreased with increased depth but irrigation method, location and depth interacted (Table 4-17). With overhead irrigation at the center of the bed, NH_4-N concentration decreased linearly with an increase in depth. With drip irrigation at the center and with either water application method at the side of the bed, soil NH_4-N concentrations were not affected by depth.

Phosphorus concentration was higher with drip than with overhead irrigation but was not affected by N-K rate (Table 4-15). Soil P was higher at the center than at the side of the bed, but irrigation method and sample location interacted (Table 4-20). With overhead irrigation, the concentration of P was not influenced by location but with drip irrigation, P concentration was higher at the center than at the side of the bed. The concentration of P decreased with an increase in depth, but location and depth interacted in their effect on P concentration (Table 4-21). At the center of the bed, sample P

Table 4-19. Soil NH_4-N and Ca concentrations as affected by irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	NH_4-N (ppm)		Ca (ppm)	
	Overhead	Drip	Overhead	Drip
135-202	4.30	0.78*[z]	22.9	11.9**
270-404	13.3	0.65**	35.0	14.2***
	NS	NS	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-20. Soil P concentration as affected by irrigation method x bed location interaction.

Location	P (ppm)	
	Overhead	Drip
Center	0.58	1.26***[z]
Side	0.63	0.80**
	NS	**

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-21. Soil P concentration as affected by bed location x soil depth interaction.

Depth (cm)	P (ppm)	
	Center	Side
0-10	1.37	0.84*[z]
10-20	0.81	0.71NS
20-30	0.57	0.59NS
	L***	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level. Effect of depth was linear (L).

values decreased linearly with greater depth but were similar at all depths at the side.

Irrigation method did not affect soil K concentration (Table 4-15). The concentration of K increased with N-K rate and was higher at the center than the side of the bed, but was influenced by an interaction between N-K rate and location (Table 4-22). At both center and side locations, K concentration increased with N-K rate but the increase was greater at the center than at the side of the bed. The concentration of K decreased with an increase in soil depth but depth interacted with irrigation method and N-K rate (Table 4-23), and with irrigation method and bed location (Table 4-17) in their effects on K concentration. With overhead irrigation with the lower N-K rate and with both irrigation methods with the higher N-K rate, K concentration decreased linearly with an increase in depth. With drip irrigation with the lower N-K rate, K concentration was similar at all soil depths. With overhead irrigation at the center of the bed the response in K concentration with an increase in depth was quadratic with the greater decrease in soil K between 0-10 cm and 10-20 cm, but at the side or with drip irrigation at either location, K concentration was similar at all depths (Table 4-17).

Soil Ca concentration was not affected by irrigation method but increased with N-K rate (Table 4-15). However, irrigation method and N-K rate interacted in their effect on Ca concentration (Table 4-19). With overhead irrigation, Ca concentration increased with N-K rate but with drip irrigation, nutrient rate did not effect Ca concentration. Soil Ca concentration was lower with samples taken

Table 4-22. Soil K concentration as affected by N-K rate x bed location interaction.

N-K rate ($kg \cdot ha^{-1}$)	K (ppm)	
	Center	Side
135-202	19.7	6.42**[z]
270-404	56.4	18.3 ***
	**	**

[z] Effects were significant at the 1% (**) or 0.1% (***) level.

Table 4-23. Soil K concentration as affected by irrigation method x N-K rate x soil depth interaction.

Depth (cm)	135-202		270-404	
	Overhead	Drip	Overhead	Drip
		K (ppm)		
0-10	46.1	8.16**[z]	113	26.5***
10-20	6.13	7.40NS	35.7	23.7NS
20-30	5.12	5.41NS	8.84	16.0**
	L*	NS	L***	L**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L).

from the side than from the center of the bed, and decreased with an increase in depth, but was affected by an interaction between these variables and irrigation method (Table 4-17). With overhead irrigation at both locations and with drip irrigation at the side of the bed, Ca concentration decreased linearly with an increase in depth, but with drip irrigation at the center, Ca concentration was not influenced by soil depth.

Magnesium concentration was not affected by method of irrigation but was higher with the higher of the 2 N-K rates (Table 4-15). The concentration of Mg was lower at the side than at the center of the bed, and decreased as depth increased, but irrigation method, location and depth interacted in their effect on Mg concentration (Table 4-17). Soil Mg concentration decreased linearly with an increase in depth with overhead irrigation at the center of the bed and with drip at the side. With overhead irrigation at the side and with drip irrigation at the center, soil Mg values were similar at all depths.

Quincy Soil Analyses

Soil pH was not affected by irrigation method or location or depth but was higher at the higher than lower N-K rate (Table 4-24). However, a significant interaction occurred between irrigation method and location of sample (Table 4-25). At the center of the bed, the pH was higher with drip than with overhead irrigation, but at the side the pH was similar with both methods of irrigation.

At Quincy, EC was higher with overhead than with drip irrigation and with the higher of the 2 N-K rates (Table 4-24). Soil EC was higher at the center than at the side of the bed and decreased with an

Table 4-24. Soil chemical characteristics after broccoli at Quincy as affected by irrigation method, N-K rate, bed location and soil depth, 1983.

Treatment	pH	EC ($dS \cdot m^{-1}$)	Soil conen (ppm) NO_3-N	NH_4-N	P	K	Ca	Mg
Irrigation (I)								
Overhead	6.24	1.84	10.5	3.00	0.27	22.7	17.1	7.07
Drip	6.27	1.18	2.83	2.70	0.21	12.0	11.2	4.18
Significance[z]	NS	**	**	NS	NS	*	*	*
N-K rate ($kg \cdot ha^{-1}$)								
135-202	6.24	1.34	2.45	2.13	0.26	11.3	13.2	5.43
270-404	6.28	1.69	10.9	2.57	0.22	23.2	15.0	5.81
Significance	***	*	**	NS	NS	***	NS	NS
Location (L)								
Center	6.26	1.67	8.81	2.53	0.35	22.9	14.7	5.74
Side	6.26	1.35	4.55	2.17	0.13	11.6	13.5	5.50
Significance	NS	*	NS	NS	*	**	NS	NS
IxL	**	*	NS	*	NS	NS	**	**
Depth (D) (cm)								
0-10	6.24	2.09	10.9	3.64	0.48	29.9	20.3	8.80
10-20	6.28	1.25	5.49	1.30	0.20	11.4	11.1	4.57
20-30	6.26	1.20	3.65	2.11	0.04	10.4	10.9	3.50
Significance	NS	***	NS	Q*	L***	***	***	***
IxD	NS	***	NS	NS	NS	L***	**	**
IxLxD	NS	*	NS	NS	NS	NS	**	**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

Table 4-25. Soil pH and NH_4-N concentration as affected by irrigation method x bed location interaction.

Location	pH Overhead	pH Drip	NH_4-N (ppm) Overhead	NH_4-N (ppm) Drip
Center	6.22	6.29**[z]	3.96	1.09**
Side	6.26	6.25NS	2.03	2.31NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 1% (**) level.

increase in depth but irrigation method, bed location and depth interacted (Table 4-26). With overhead irrigation at the center of the bed, the greatest decrease in soil Mg occurred from the 0-10 to the 10-20 cm soil depth with little further reduction at the 20-30 cm depth. Values were similar at all depths at the side of the bed with overhead irrigation or at the center with drip, but at the side of the bed with drip irrigation, EC decreased linearly as depth increased.

The NO_3-N concentration was higher with overhead than with drip and with the 270-404 $kg \cdot ha^{-1}$ N-K rate than the 135-202 rate (Table 4-24). Soil NO_3-N concentration was not influenced by bed location or soil depth.

Ammonium concentration was similar with drip or overhead irrigation and did not vary significantly due to N-K rate or bed location, but irrigation method and location interacted (Table 4-25). The concentration of NH_4-N at the center of the bed was greater with overhead than with drip irrigation but was similar with both irrigation methods at the side. Location of sample did not affect NH_4-N concentration with either irrigation method. Soil NH_4-N concentration decreased significantly from the 0-10 to the 10-20 cm depth, then increased at the 20-30 cm depth (Table 4-24).

Soil K, Ca and Mg concentrations were higher with overhead than with drip irrigation, and K concentration was higher with the higher N-K rate. Soil K concentration was higher at the center than at the side of the bed, and the concentrations of K, Ca and Mg decreased with increased depth. Irrigation method and soil depth interacted in their effect on soil K concentration (Table 4-27). At the 0-10 cm depth,

Table 4-26. Soil EC and Ca and Mg concentrations as affected by irrigation method x bed location x soil depth interaction.

Location and depth (cm)	EC ($dS \cdot m^{-1}$)		Ca (ppm)		Mg (ppm)	
	Overhead	Drip	Overhead	Drip	Overhead	Drip
Center						
0-10	3.57	1.20	34.3	9.6	15.4	3.41
10-20	1.57	1.11	13.6	8.3	6.02	2.79
20-30	1.43	1.17	11.9	10.7	4.13	2.77
	L***Q*[z]	NS	L***Q*	NS	L***	NS
Side						
0-10	2.08	1.53	19.8	17.7	8.41	8.01
10-20	1.20	1.10	11.1	11.5	4.63	4.83
20-30	1.20	0.98	11.8	9.19	3.86	3.25
	NS	L***	NS	L***	L*	L***

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

Table 4-27. Soil K concentration as affected by irrigation method x soil depth interaction.

Depth (cm)	K (ppm)	
	Overhead	Drip
0-10	46.7	13.1**[z]
10-20	12.0	10.8NS
20-30	9.33	11.5NS
	L***Q**	NS

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

soil K concentration was higher with overhead than with drip irrigation but irrigation method did not affect K concentrations at the 2 lower soil depths. With overhead irrigation, soil K concentration decreased significantly from the 0-10 to the 10-20 cm depth and slightly at the 20-30 cm depth. With drip irrigation, concentrations of K were similar at all depths. Irrigation method, bed location and soil depth interacted to affect soil Ca and Mg concentrations (Table 4-26). With overhead irrigation at the bed center, soil Ca concentration decreased significantly between the 0-10 and 10-20 cm depths but was reduced slightly at the 20-30 cm depth. At the side of the bed and with drip irrigation at the center, Ca concentrations were similar at all depths but with drip irrigation at the side of the bed, values decreased linearly with an increase in depth. Soil Mg concentration decreased linearly with increased soil depth with overhead irrigation with each bed location and with drip irrigation at the side but with drip at the bed center, soil Mg concentration did not differ between depths.

1984 Tomato Field Experiment

Yield

Gainesville. Early tomato yield (harvest 1 + 2) was not affected by treatment (Table 4-28). However, N-K rate and time of fertilizer application interacted in their effect on early large fruit yield (Table 4-29). With fall application, yield increased with N-K rate but with fall and spring nutrient application, N-K rate did not affect yield of large fruit. With the lower N-K rate, yield of large tomato

Table 4-28. Total early season tomato yield as affected by irrigation method, N-K rate and time at Gainesville.

Treatment	Size[z]			
	Large	Medium	Small	Total
	Yield ($t \cdot ha^{-1}$)			
Irrigation				
Overhead	5.7	3.5	0.9	10.1
Drip	4.5	2.8	0.8	8.1
Significance[y]	NS	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	4.3	2.8	0.9	8.0
270-404	5.9	3.5	0.8	10.2
Significance	NS	NS	NS	NS
Time (T)				
Fall	4.2	3.4	1.1	8.7
Fall + spring	6.0	3.0	0.6	9.6
Significance	NS	NS	NS	NS
RxT	*	NS	NS	NS

[z] Mean fruit weights for sizes were large: 205 g, medium: 150 g, and small: <115 g.

[y] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-29. Total early season large tomato yield as affected by N-K rate x time interaction at Gainesville.

N-K rate ($kg \cdot ha^{-1}$)	Yield ($t \cdot ha^{-1}$)	
	Fall	Fall + spring
135-202	2.0	6.6***[z]
270-404	6.4	5.4NS
	**	NS

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

fruit was higher with fall + spring than with fall-only nutrient application but with the 270-404 $kg \cdot ha^{-1}$ N-K rate, time of application did not affect early yield of large fruit.

Irrigation method did not affect mid-season (harvests 3 + 4) tomato yield (Table 4-30). Large, total marketable (large + medium + small) and total (marketable + cull) tomato yields increased with N-K rate but yields of medium, small and cull tomatoes were not affected by N-K rate (Table 4-30). The yield of large fruit, however, was influenced by an interaction between irrigation method and N-K rate (Table 4-31). With overhead irrigation, large fruit yield increased with an increase in N-K rate, but with drip irrigation, N-K rate did not affect mid-season yield of large fruit. With either N-K application rate, irrigation method did not influence large fruit yield. Fall + spring nutrient application resulted in higher tomato yields in all categories than did fall-only application (Table 4-30) but irrigation method and application time interacted in their effects on large, total marketable and total tomato yields (Table 4-32). With fall applied N-K, yields in all 3 categories were higher with overhead than with drip irrigation, but with fall + spring application, irrigation method did not affect these yields. With both irrigation methods, higher yields resulted with the fall + spring than with the fall fertilization time. Irrigation method, N-K rate and time interacted in their effect on yield of small tomatoes (Table 4-33). With fall application with overhead irrigation, small tomato yield increased with N-K rate but with fall fertilization with drip irrigation, N-K rate did not affect yield of small fruit. With fall +

Table 4-30. Total mid-season tomato yield as affected by irrigation method, N-K rate and time at Gainesville.

Treatment	Size[z]			Marketable	Cull	Total
	Large	Medium	Small			
				Yield ($t \cdot ha^{-1}$)		
Irrigation (I)						
Overhead	8.7	5.8	1.9	16.4	0.7	17.1
Drip	8.5	5.3	2.1	15.9	0.9	16.8
Significance[y]	NS	NS	NS	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)						
135-202	7.3	5.1	2.1	14.5	0.8	15.2
270-404	10.0	5.9	1.9	17.8	0.7	18.6
Significance	**	NS	NS	*	NS	*
IxR	*	NS	NS	NS	NS	NS
Time (T)						
Fall	3.0	2.6	1.5	7.1	0.3	7.4
Fall + spring	14.3	8.5	2.5	25.3	1.2	26.5
Significance	***	***	***	***	***	***
IxT	**	NS	NS	*	NS	*
IxRxT	NS	NS	**	NS	NS	NS

[z] Mean fruit weights for sizes were large: 205 g, medium: 150 g and small: <115 g.

[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-31. Total mid-season large tomato yield as affected by irrigation method x N-K rate interaction at Gainesville.

N-K rate ($kg \cdot ha^{-1}$)	Yield ($t \cdot ha^{-1}$)	
	Overhead	Drip
135-202	6.5	8.1NS[z]
270-404	10.9	9.0NS
	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-32. Total mid-season large, marketable and total tomato yields as affected by irrigation method x time interaction at Gainesville.

Irrigation	Large		Marketable		Total	
	Fall	Fall + spring	Fall	Fall + spring	Fall	Fall + spring
			Yield ($t \cdot ha^{-1}$)			
Overhead	4.4	13.0***[z]	9.1	23.7***	9.4	24.7***
Drip	1.5	15.6***	4.9	26.9***	5.2	28.2***
	**	NS	*	NS	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-33. Total mid-season small tomato yield as affected by irrigation method x N-K rate x time interaction at Gainesville.

N-K rate ($kg \cdot ha^{-1}$)	Fall		Fall + spring	
	Overhead	Drip	Overhead	Drip
		Yield ($t \cdot ha^{-1}$)		
135-202	1.1	2.0NS[z]	2.7	2.6NS
270-404	1.7	1.1*	2.2	2.7NS
	*	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

spring fertilizer application, N-K rate or irrigation method had no effect on mid-season yield of small tomatoes. With fall application with the lower N-K rate, yields were similar with either irrigation method but with fall fertilization with the higher N-K rate, mid-season small fruit yield was higher with overhead than with drip irrigation.

Late season tomato yield (harvest 5 + 6) was not affected by irrigation method or N-K rate (Table 4-34). Yields in all categories were higher with the fall + spring than with the fall application of N-K (Table 4-34). However, irrigation method and nutrient application time interacted in their effects on yield of large, medium and total marketable tomato fruit (Table 4-35). With fall applied N-K, irrigation method did not influence yields but with fall + spring nutrient application, yields in all 3 categories were higher with overhead than with drip irrigation. With each irrigation method, yields were higher with fall + spring than with fall fertilization.

At Gainesville, total yield of large fruit (early + mid + late yields) was higher with overhead than with drip irrigation and with the higher than lower N-K rate (Table 4-36). Yield of other categories was not affected by irrigation method or N-K rate, but all were higher with fall + spring N-K application than with the residual fall-only fertilization.

Quincy. Early season tomato yield was not affected by irrigation method or N-K rate (Table 4-37). Marketable, cull and total weights were higher with fall than with fall + spring nutrient application (Table 4-37) but N-K rate and time interacted in their effects on

Table 4-34. Total late season tomato yield as affected by irrigation method, N-K rate and time at Gainesville.

Treatment	Size[z]			Total
	Large	Medium	Small	
		Yield ($t \cdot ha^{-1}$)		
Irrigation (I)				
Overhead	1.5	1.3	1.3	4.1
Drip	0.7	0.7	1.0	2.4
Significance[y]	NS	NS	NS	NS
N-K rate ($kg \cdot ha^{-1}$)				
135-202	0.9	1.0	1.0	2.9
270-404	1.3	1.0	1.3	3.6
Significance	NS	NS	NS	NS
Time (T)				
Fall	0.1	0.2	0.4	0.7
Fall + spring	2.1	1.8	1.9	5.7
Significance	***	***	***	***
IxT	**	**	NS	**

[z] Mean fruit weights for sizes were large: 205 g, medium: 150 g, and small: <115 g.

[y] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-35. Total late season large, marketable and total tomato yields as affected by irrigation method x time interaction at Gainesville.

Irrigation	Large		Marketable		Total	
	Fall	Fall + spring	Fall	Fall + spring	Fall	Fall + spring
			Yield ($t \cdot ha^{-1}$)			
Overhead	0.2	2.8***[z]	0.3	2.4***	1.0	7.3***
Drip	0.1	1.4***	0.1	1.2***	0.5	4.2***
	NS	**	NS	**	NS	**

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-36. Total tomato yield as affected by irrigation method, N-K rate and time at Gainesville.

Treatment	Size[z]			Total marketable	Cull	Total
	Large	Medium	Small			
				Yield ($t \cdot ha^{-1}$)		
Irrigation						
Overhead	15.9	10.6	4.1	30.6	0.7	31.3
Drip	13.8	8.8	3.9	26.5	0.8	27.3
Significance[y]	*	NS	NS	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)						
135-202	12.5	8.9	4.0	25.4	0.8	26.2
270-404	17.2	10.5	4.0	31.7	0.8	32.5
Significance	*	NS	NS	NS	NS	NS
Time						
Fall	7.3	6.1	3.0	16.4	0.3	16.7
Fall + spring	22.4	13.3	5.0	40.7	1.2	41.8
Significance	***	***	***	***	**	***

[z] Mean fruit weights for sizes were large: 205 g, medium: 150 g and small: <115 g.

[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-37. Early season tomato yield as affected by irrigation method, N-K rate and time at Quincy.

Treatment	Marketable			Cull		Total ($t \cdot ha^{-1}$)
	Wt ($kg \cdot ha^{-1}$)	No. ($1000 \cdot ha^{-1}$)	Avg wt (g)	Wt ($kg \cdot ha^{-1}$)	No. ($1000 \cdot ha^{-1}$)	
Irrigation						
Overhead	406	1.88	216	941	5.02	1.35
Drip	331	1.79	185	703	5.15	1.03
Significance[z]	NS	NS	NS	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)						
135-202	309	1.61	192	888	5.56	1.20
270-404	429	2.06	208	756	4.61	1.18
Significance	NS	NS	NS	NS	NS	NS
Time (T)						
Fall	506	2.38	212	1050	5.92	1.55
Fall + spring	251	1.30	192	597	4.26	0.83
Significance	*	NS	NS	*	NS	*
RxT	*	*	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

weight and number of marketable fruit (Table 4-38). With the 135-202 $kg \cdot ha^{-1}$ N-K rate, application time did not affect weight or number of marketable tomatoes, but with the higher rate both weight and number were higher with fall than with fall + spring nutrient application. Rate of N-K did not influence weight or number of marketable fruit with either time of application.

At mid-season (2nd harvest) weight and number of marketable and cull tomatoes and total weight were higher with overhead than with drip irrigation, but irrigation method did not influence average weight of marketable fruit (Table 4-39). Rate and time of N-K application had no effect on any yield parameter at the 2nd time of harvest.

The number of cull fruit was higher with overhead than with drip irrigation, but irrigation method did not affect any other yield category at the final harvest (Table 4-40). Rate of N-K did not influence late tomato yield at Quincy. All yield categories except average fruit weight were higher with the fall + spring than with the fall time of fertilization but N-K rate and time interacted in their effect on weight and number of marketable tomato fruit (Table 4-41). With the lower N-K rate, both weight and number of fruit were higher with fall + spring than fall application of nutrients, but with the higher rate, similar values resulted with both application times. Rate of N-K had no effect on weight or number of marketable tomato fruit with either fall or fall + spring nutrient application.

At Quincy, weight and number of marketable and cull tomatoes and total weight (marketable + cull) were higher with overhead than with

Table 4-38. Early season marketable tomato yield as affected by N-K rate x time interaction at Quincy.

N-K rate ($kg \cdot ha^{-1}$)	Wt ($kg \cdot ha^{-1}$)		No. ($1000 \cdot ha^{-1}$)	
	Fall	Fall + spring	Fall	Fall + spring
135-202	293	325NS[z]	1.43	1.79NS
270-404	719	138**	3.32	0.81*
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-39. Mid-season tomato yield as affected by irrigation method, N-K rate and time at Quincy.

Treatment	Marketable			Cull		Total ($t \cdot ha^{-1}$)
	Wt ($t \cdot ha^{-1}$)	No. ($1000 \cdot ha^{-1}$)	Avg wt (g)	Wt ($t \cdot ha^{-1}$)	No. ($1000 \cdot ha^{-1}$)	
Irrigation						
Overhead	5.9	29.0	202	14.7	83.5	20.6
Drip	2.5	12.8	194	5.3	35.5	7.7
Significance[z]	*	**	NS	**	*	*
N-K rate ($kg \cdot ha^{-1}$)						
135-202	4.1	20.6	198	9.1	58.0	13.7
270-404	4.3	21.2	202	10.3	61.0	14.6
Significance	NS	NS	NS	NS	NS	NS
Time						
Fall	4.2	20.5	204	11.3	65.3	15.5
Fall + spring	4.2	21.2	196	8.6	53.7	12.8
Significance	NS	NS	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-40. Late season tomato yield as affected by irrigation method, N-K rate and time at Quincy.

Treatment	Marketable Wt ($t \cdot ha^{-1}$)	Marketable No. ($1000 \cdot ha^{-1}$)	Marketable Avg wt (g)	Cull Wt ($t \cdot ha^{-1}$)	Cull No. ($1000 \cdot ha^{-1}$)	Total ($t \cdot ha^{-1}$)
Irrigation						
Overhead	5.0	24.2	208	31.1	197	36.1
Drip	3.0	14.1	211	19.3	120	21.0
Significance[z]	NS	NS	NS	NS	*	NS
N-K rate (R) ($kg \cdot ha^{-1}$)						
135-202	4.3	21.0	206	23.2	149	27.5
270-404	3.7	17.3	213	27.2	169	30.9
Significance	NS	NS	NS	NS	NS	NS
Time (T)						
Fall	2.7	13.1	206	18.7	120	21.4
Fall + spring	5.3	25.1	212	31.7	197	37.0
Significance	**	**	NS	**	**	**
RxT	*	*	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-41. Late season marketable tomato yield as affected by N-K rate x time interaction at Quincy.

N-K rate ($kg \cdot ha^{-1}$)	Wt ($t \cdot ha^{-1}$)		No. ($1000 \cdot ha^{-1}$)	
	Fall	Fall + spring	Fall	Fall + spring
135-202	2.1	6.5*[z]	10.8	31.3*
270-404	3.3	4.1NS	15.5	19.0NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

drip irrigation, but average marketable fruit weight was not affected by irrigation method (Table 4-42). Rate and time of N-K application did not affect any yield parameter but interacted in their effects on weight and number of marketable tomatoes (Table 4-43). With the lower N-K rate, weight and number of fruit were higher with fall + spring than with fall nutrient application but with the higher rate, time of application did not influence either variable. Rate of N-K did not affect weight or number of marketable tomato fruit with either time of fertilization.

Tissue Analyses

Seven weeks after transplanting, tomato leaf N concentration was higher at Quincy than at Gainesville (Table 4-44). Tissue N concentrations were similar at both locations in leaves and fruit sampled 14 weeks after transplanting but was higher at Gainesville than Quincy in the plant. Irrigation method did not influence N concentration in early leaf, fruit or plant samples, but in the 2nd leaf sample N concentration was higher with overhead than with drip irrigation. However, location and irrigation method interacted in their effect on N concentration in the first leaf sample (Table 4-45). With overhead irrigation the concentration of N was higher at Quincy than at Gainesville, but with drip irrigation, values were similar at both locations. Rate of N-K application did not affect total N concentration in any plant tissue sampled (Table 4-44). The concentration of N was higher with fall + spring than with fall nutrient application in the early leaf (7 weeks after transplanting) and fruit samples but was not affected by time of N-K application in

Table 4-42. Total tomato yield as affected by irrigation method, N-K rate and time at Quincy.

Treatment	Marketable			Cull		Total
	Wt ($t \cdot ha^{-1}$)	No. ($1000 \cdot ha^{-1}$)	Avg wt (g)	Wt ($t \cdot ha^{-1}$)	No. ($1000 \cdot ha^{-1}$)	($t \cdot ha^{-1}$)
Irrigation						
Overhead	11.3	55.0	205	46.7	286	58.0
Drip	5.9	28.7	201	25.3	161	31.1
Significance[z]	*	*	NS	*	**	*
N-K rate (R) ($kg \cdot ha^{-1}$)						
135-202	8.7	43.2	201	33.8	213	42.5
270-404	8.4	40.5	207	38.2	234	46.6
Significance	NS	NS	NS	NS	NS	NS
Time (T)						
Fall	7.4	36.0	205	31.0	192	38.4
Fall + spring	9.7	47.7	203	40.9	255	50.6
Significance	NS	NS	NS	NS	NS	NS
RxT	*	*	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-43. Total marketable tomato yield and number of fruit as affected by N-K rate x time interaction at Quincy.

N-K rate ($kg \cdot ha^{-1}$)	Wt ($t \cdot ha^{-1}$)		No. ($1000 \cdot ha^{-1}$)	
	Fall	Fall + spring	Fall	Fall + spring
135-202	5.2	12.2*[z]	26.0	60.4*
270-404	9.6	7.2NS	46.0	35.0NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-44. Nitrogen concentration of tomato as affected by location, irrigation method, N-K rate and time.

Treatment	N conc (%)			
	Leaf 1[z]	Leaf 2	Fruit	Plant
Location (L)				
Gainesville	3.15	2.91	2.00	1.98
Quincy	3.86	2.62	1.86	1.34
Significance[y]	*	NS	NS	*
Irrigation (I)				
Overhead	3.50	2.98	2.00	1.66
Drip	3.53	2.55	1.86	1.66
Significance	NS	**	NS	NS
LxI	*	NS	NS	**
N-K rate ($kg \cdot ha^{-1}$)				
135-202	3.46	2.86	1.93	1.60
270-404	3.55	2.67	1.93	1.72
Significance	NS	NS	NS	NS
Time (T)				
Fall	2.96	2.68	1.78	1.65
Fall + spring	4.05	2.85	2.08	1.67
Significance	***	NS	***	NS
LxIxT	NS	NS	NS	*

[z] Leaf 1 and 2 samples taken at 7 and 14 weeks after transplanting.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-45. Tomato leaf N concentration 7 weeks after transplanting as affected by location x irrigation method interaction.

Irrigation	N conc (%)	
	Gainesville	Quincy
Overhead	2.99	3.97*
Drip	3.32	3.74NS
	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

the 2nd leaf or whole plant samples. Plant N concentration, however, was influenced by an interaction between location, irrigation method and time (Table 4-46). At Gainesville with fall nutrient application, plant N concentration was higher with drip than with overhead irrigation but irrigation method did not affect N concentration with the fall + spring time of application. At Quincy, irrigation method did not influence plant N concentration with fall nutrient application but with fall + spring N-K application the concentration of plant N was higher with overhead than with drip irrigation.

Tissue P concentration in all samples was significantly higher at Gainesville than Quincy (Table 4-47). Concentrations were similar with overhead and drip irrigation. Leaf P concentration at both samplings (7 and 14 weeks after transplanting) decreased with an increase in N-K rate, but fruit and whole plant P concentrations were not affected by N-K rate. Concentration of P was higher with fall than with fall + spring nutrient application in all tissues except fruit. Location, irrigation method and time interacted in their effect on plant P concentration (Table 4-48), and location, irrigation method, N-K rate and time combined to influence P concentration in leaf and fruit tissues 14 weeks after transplanting (Table 4-49). At Gainesville with both fertilization times and at Quincy with the fall nutrient application, irrigation method did not affect plant P concentration but at Quincy with the fall + spring fertilization, plant P concentration was higher with overhead than with drip irrigation (Table 4-48). At Gainesville with overhead irrigation and

Table 4-46. Tomato plant N concentration as affected by location x irrigation method x time interaction.

Location and irrigation	N concn (%)	
	Fall	Fall + spring
Gainesville		
Overhead	1.74	2.06NS[z]
Drip	2.42	1.70***
	**	NS
Quincy		
Overhead	1.23	1.60*
Drip	1.21	1.32NS
	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-47. Phosphorus concentration of tomato as affected by location, irrigation method, N-K rate and time.

Treatment	P concn (%)			
	Leaf 1[z]	Leaf 2	Fruit	Plant
Location (L)				
Gainesville	0.68	0.43	0.62	0.59
Quincy	0.52	0.20	0.38	0.20
Significance[y]	***	***	**	***
Irrigation (I)				
Overhead	0.59	0.32	0.47	0.39
Drip	0.60	0.32	0.53	0.40
Significance	NS	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	0.62	0.33	0.51	0.42
270-404	0.57	0.31	0.49	0.38
Significance	*	*	NS	NS
Time (T)				
Fall	0.63	0.34	0.50	0.44
Fall + spring	0.57	0.30	0.49	0.35
Significance	**	***	NS	***
LxIxT	NS	NS	NS	*
LxIxRxT	NS	*	*	NS

[z] Leaf 1 and 2 samples taken at 7 and 14 weeks after transplanting.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-48. Tomato plant P concentration as affected by location x irrigation method x time interaction.

Location and irrigation	P conon (%)	
	Fall	Fall + spring
Gainesville		
Overhead	0.66	0.52*[z]
Drip	0.65	0.55*
	NS	NS
Quincy		
Overhead	0.19	0.20NS
Drip	0.27	0.14**
	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-49. Tomato leaf and fruit P concentrations 14 weeks after transplanting as affected by location x irrigation method x N-K rate x time interaction.

Location, irrigation, and N-K rate ($kg \cdot ha^{-1}$)	Leaf		Fruit	
	Fall	Fall + spring	Fall	Fall + spring
		P conon (%)		
Gainesville				
Overhead				
135-202	0.57	0.39***[z]	0.58	0.69*
270-404	0.45	0.37*	0.61	0.55NS
	**	NS	NS	*
Drip				
135-202	0.44	0.37*	0.60	0.58NS
270-404	0.45	0.39NS	0.66	0.70NS
	NS	NS	NS	NS
Quincy				
Overhead				
135-202	0.18	0.19NS	0.39	0.27NS
270-404	0.19	0.19NS	0.30	0.34NS
	NS	NS	NS	NS
Drip				
135-202	0.23	0.22NS	0.47	0.45NS
270-404	0.20	0.24NS	0.40	0.37NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

fall nutrient application, P concentration in leaf tissue sampled 14 weeks after transplanting decreased with an increase in N-K rate, but N-K rate did not influence leaf P concentration with any other treatment combination (Table 4-49). Fruit P concentration decreased with an increase in N-K rate at Gainesville with overhead irrigation and fall + spring nutrient application, but was not affected by N-K rate with any other treatment combination (Table 4-49).

Leaf K concentrations were similar at both locations at both times of sampling, but fruit and whole plant K concentrations were higher at Gainesville than at Quincy (Table 4-50). Fourteen weeks after transplanting, leaf K concentration was higher with overhead than with drip irrigation but at all other times of sampling, tissue K was not influenced by irrigation method. Tissue K concentrations increased with N-K rate in all but the fruit, and were higher in all tissue with the fall + spring than with the fall nutrient application. However, location, N-K rate and time interacted in their effects on K concentration of the 2nd leaf and whole plant tissues (Table 4-51). At Gainesville with both application times and at Quincy with fall fertilization, N-K rate did not influence 2nd leaf or plant K concentrations but at Quincy with fall + spring fertilization, K concentrations in both tissues increased with N-K rate. Location, irrigation method, N-K rate and time combined to influence first leaf and fruit K concentrations (Table 4-52). Early leaf K concentration increased with rate of fall applied N-K at Gainesville with overhead and at Quincy with drip irrigation. Rate of N-K did not affect leaf K concentration with fall application at either Gainesville with drip or

Table 4-50. Potassium concentration of tomato as affected by location, irrigation method, N-K rate and time.

Treatment	K conen (%)			
	Leaf 1[z]	Leaf 2	Fruit	Plant
Location (L)				
Gainesville	2.59	1.98	4.17	3.06
Quincy	2.42	1.68	3.79	1.43
Significance[y]	NS	NS	*	**
Irrigation (I)				
Overhead	2.62	2.01	4.02	2.38
Drip	2.40	1.64	3.93	2.11
Significance	NS	**	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	2.39	1.67	3.87	2.10
270-404	2.63	1.99	4.09	2.39
Significance	**	*	NS	**
Time (T)				
Fall	2.11	1.69	3.77	2.06
Fall + spring	2.91	1.96	4.19	2.43
Significance	***	*	**	**
LxRxT	NS	*	NS	*
LxIxRxT	*	NS	**	NS

[z] Leaf 1 and 2 samples taken at 7 and 14 weeks after transplanting.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-51. Potassium concentration of tomato leaf 14 weeks after transplanting and plant as affected by location x N-K rate x time interaction.

Location and N-K rate ($kg \cdot ha^{-1}$)	Leaf		Plant	
	Fall	Fall + spring	Fall	Fall + spring
		K conen (%)		
Gainesville				
135-202	1.78	1.96NS[z]	2.86	3.13NS
270-404	1.99	2.18NS	3.16	3.10NS
	NS	NS	NS	NS
Quincy				
135-202	1.55	1.37NS	1.08	1.33NS
270-404	1.46	2.34*	1.15	2.14***
	NS	**	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-52. Potassium concentration of tomato leaf 7 weeks after transplanting and fruit as affected by location x irrigation method x N-K rate x time interaction.

Location, irrigation and N-K rate ($kg \cdot ha^{-1}$)	Leaf		Fruit	
	Fall	Fall + spring	Fall	Fall + spring
		K conen (%)		
Gainesville				
Overhead				
135-202	1.93	3.24***[z]	3.69	4.74**
270-404	2.55	3.43*	4.41	4.30NS
	**	NS	NS	*
Drip				
135-202	1.95	2.66*	3.60	3.95NS
270-404	2.01	2.99***	3.98	4.66NS
	NS	NS	NS	NS
Quincy				
Overhead				
135-202	2.36	2.51NS	3.78	3.60NS
270-404	2.28	2.66NS	3.59	4.09NS
	NS	NS	NS	NS
Drip				
135-202	1.63	2.84**	3.41	4.21NS
270-404	2.18	2.93*	3.73	3.94NS
	*	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Quincy with overhead irrigation, or with fall + spring fertilization at either location with overhead or drip irrigation. Rate of fall applied N-K did not influence fruit K concentration at either location with either irrigation method. With fall + spring fertilization at Gainesville with overhead irrigation, fruit K concentration was higher with the lower N-K rate but was not affected by N-K rate with all other treatment combinations.

Tomato tissue Ca concentration was not affected by location or irrigation method (Table 4-53). At the first time of sampling, leaf Ca concentration decreased with an increase in N-K rate, but N-K rate did not influence the Ca concentration in later tissue samples. Location and N-K rate, and irrigation method and N-K rate interacted in their effects on leaf Ca 14 weeks after transplanting (Table 4-54). At Gainesville, leaf Ca concentration decreased with an increase in N-K rate but at Quincy, values were similar with both N-K rates. With overhead irrigation, leaf Ca concentration was higher with the lower N-K rate but with drip irrigation, N-K rate did not influence leaf Ca concentration. The concentration of Ca in both leaf samples was higher with fall than fall + spring fertilization, but fruit and plant Ca concentrations were not affected by time of nutrient application (Table 4-53). However, location and time (Table 4-55) and location, irrigation method and time (Table 4-56) interacted in their effects on whole plant and early leaf Ca concentrations. At Gainesville, plant Ca concentration was not affected by N-K application time, but at Quincy plant Ca concentration was higher with fall than with fall + spring applied nutrients (Table 4-55).

Table 4-53. Calcium concentration of tomato as affected by location, irrigation method, N-K rate and time.

Treatment	Ca concn (%)			
	Leaf 1[z]	Leaf 2	Fruit	Plant
Location (L)				
Gainesville	2.42	3.76	0.19	2.64
Quincy	1.85	3.54	0.15	2.70
Significance[y]	NS	NS	NS	NS
Irrigation (I)				
Overhead	1.97	3.80	0.17	2.83
Drip	2.29	3.49	0.16	2.51
Significance	NS	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	2.27	3.76	0.16	2.61
270-404	1.99	3.54	0.17	2.73
Significance	***	NS	NS	NS
LxR	NS	**	NS	NS
IxR	NS	*	NS	NS
Time (T)				
Fall	2.23	3.83	0.17	2.72
Fall + spring	2.03	3.47	0.16	2.62
Significance	**	**	NS	NS
LxT	***	NS	NS	***

[z] Leaf 1 and 2 samples taken at 7 and 14 weeks after transplanting.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-54. Tomato leaf Ca concentration 14 weeks after transplanting as affected by N-K rate x location and N-K rate x irrigation method interactions.

N-K rate ($kg \cdot ha^{-1}$)	Location		Irrigation	
	Gainesville	Quincy	Overhead	Drip
	Ca concn (%)			
135-202	4.06	3.46	4.09	3.43**[z]
270-404	3.45	3.62	3.52	3.55NS
	**	NS	**	NS

[z] Effects were not significant (NS) or significant at the 1% (**) level.

Table 4-55. Tomato plant Ca concentration as affected by location x time interaction.

Time	Ca concn (%)	
	Gainesville	Quincy
Fall	2.43	3.01
Fall + spring	2.84	2.39
	NS[z]	*

[z] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-56. Tomato leaf Ca concentration 7 weeks after transplanting as affected by location x irrigation method x time interaction.

Irrigation	Fall		Fall + spring	
	Gainesville	Quincy	Gainesville	Quincy
	Ca concn (%)			
Overhead	2.34	1.79**[z]	2.04	1.72*
Drip	3.00	1.80**	2.29	2.08NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Irrigation method did not influence early leaf Ca concentration at either location with either time of fertilization (Table 4-56). With fall applied N-K and both irrigation methods and with fall + spring application with overhead irrigation, leaf Ca concentration was higher at Gainesville than at Quincy but with fall + spring fertilization with drip irrigation, values were similar at each location.

Fourteen weeks after transplanting, leaf Mg concentration was higher at Quincy than at Gainesville, but tissue Mg concentrations were similar at both locations at all other times of sampling (Table 4-57). The concentration of Mg was higher with overhead than with drip irrigation in the 2nd leaf and whole plant samples, but was not affected by irrigation method in the first leaf or fruit samples. Whole plant Mg concentration was influenced by an interaction between location and irrigation method (Table 4-58). At Gainesville, irrigation method did not affect plant Mg concentration but at Quincy the concentration of Mg was higher with overhead than with drip irrigation. Early leaf Mg concentration was higher with the lower rate of N-K but the Mg concentration of the 2nd leaf and plant samples was not influenced by N-K rate (Table 4-57). Fruit Mg concentration increased significantly with N-K rate but the difference in values was only 0.01%. First and 2nd leaf and plant Mg concentrations were not affected by time of N-K application but fruit Mg concentration was higher with fall + spring than with fall fertilization. However, location, N-K rate and application time interacted in their effect on plant Mg concentration (Table 4-59). Whole plant Mg concentration was not affected by N-K rate at either location with either time of

Table 4-57. Magnesium concentration of tomato as affected by location, irrigation method, N-K rate and time.

Treatment	Mg conc (%)			
	Leaf 1[z]	Leaf 2	Fruit	Plant
Location (L)				
Gainesville	0.45	0.44	0.19	0.60
Quincy	0.69	0.68	0.19	0.90
Significance[y]	NS	*	NS	NS
Irrigation (I)				
Overhead	0.56	0.59	0.19	0.80
Drip	0.58	0.53	0.19	0.69
Significance	NS	**	NS	*
LxI	NS	NS	NS	*
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	0.59	0.57	0.19	0.74
270-404	0.55	0.55	0.20	0.75
Significance	*	NS	*	NS
Time (T)				
Fall	0.56	0.56	0.19	0.78
Fall + spring	0.58	0.55	0.20	0.71
Significance	NS	NS	**	NS
LxRxT	NS	NS	NS	**
LxIxRxT	*	NS	*	NS

[z] Leaf 1 and 2 samples taken at 7 and 14 weeks after transplanting.
[y] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-58. Tomato plant Mg concentration as affected by irrigation method x location interaction.

Irrigation	Mg conc (%)	
	Gainesville	Quincy
Overhead	0.59	1.02
Drip	0.60	0.78
	NS[z]	*

[z] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-59. Tomato plant Mg concentration as affected by location x N-K rate x time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
		Mg conen (%)		
135-202	0.58	0.65NS[z]	0.85	0.89NS
270-404	0.56	0.59NS	1.11	0.73*
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

nutrient application. At Gainesville with both N-K rates and at Quincy with the lower rate, the concentration of plant Mg was similar with both fertilization times but at Quincy with the higher N-K rate, plant Mg concentration was higher with fall than with fall + spring time of application. The Mg concentration of early leaf and fruit tissue was influenced by an interaction between location, irrigation method, rate and time of nutrient application but the effect on early leaf Mg was primarily due to location and the significant differences in fruit Mg values ranged only from 0.02 to 0.05% (Table 4-60).

Dry matter percentage of tomato fruit was higher at Quincy than at Gainesville but was not affected by irrigation method, N-K rate or time of nutrient application (Table 4-61).

Tomato plant fresh weight was higher at Gainesville than at Quincy. Plant dry weights were similar at both locations but dry matter percentage and number of plants·ha^{-1} were higher at Quincy than at Gainesville. Plant fresh and dry weights were higher with overhead than with drip irrigation but dry matter percentage and number of plants·ha^{-1} were not affected by irrigation method. Plant fresh and dry weight and dry matter percentage increased with N-K rate but plant stand was not affected by N-K rate. Dry matter percentage, however, was influenced by an interaction between location, irrigation method and N-K rate (Table 4-62). At Gainesville with both N-K rates and at Quincy with the higher rate, dry matter percentage was not influenced by irrigation method but at Quincy with the lower N-K rate plant dry matter percentage was higher with drip than with overhead

Table 4-60. Magnesium concentration of tomato leaf 7 weeks after transplanting and fruit as affected by location x irrigation method x N-K rate x time interactions.

Location, irrigation, and N-K rate ($kg \cdot ha^{-1}$)	Leaf		Fruit	
	Fall	Fall + spring	Fall	Fall + spring
		Mg concn (%)		
Gainesville				
Overhead				
135-202	0.43	0.46NS[z]	0.17	0.22**
270-404	0.43	0.44NS	0.20	0.20NS
	NS	NS	NS	*
Drip				
135-202	0.53	0.45NS	0.17	0.19NS
270-404	0.43	0.42NS	0.19	0.21NS
	NS	NS	NS	NS
Quincy				
Overhead				
135-202	0.77	0.65NS	0.19	0.19NS
270-404	0.61	0.67NS	0.18	0.20NS
	NS	NS	NS	NS
Drip				
135-202	0.64	0.83NS	0.18	0.20NS
270-404	0.63	0.75NS	0.19	0.20NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-61. Tomato fruit dry matter percentage and plant fresh and dry weights, dry matter percentage and number as affected by location, irrigation method, N-K rate and time.

Treatment	Fruit Dry matter (%)	Plant Fresh wt (kg)	Plant Dry wt (g)	Plant Dry matter (%)	Plant No. ($1000 \cdot ha^{-1}$)
Location (L)					
Gainesville	4.88	1.74	195	11.4	11.5
Quincy	5.66	0.74	113	17.7	12.2
Significance[z]	*	*	NS	*	*
Irrigation (I)					
Overhead	5.15	1.38	174	13.3	12.1
Drip	5.39	1.09	135	15.7	11.6
Significance	NS	**	*	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)					
135-202	5.25	1.05	135	15.4	12.0
270-404	5.28	1.43	174	13.6	11.7
Significance	NS	**	*	***	NS
LxIxR	NS	NS	NS	*	NS
Time (T)					
Fall	5.21	0.81	106	15.1	11.9
Fall + spring	5.33	1.67	203	13.9	11.8
Significance	NS	***	***	*	NS
LxT	NS	**	**	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-62. Tomato plant dry matter percentage as affected by location x N-K rate x irrigation method interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville Overhead	Gainesville Drip	Quincy Overhead	Quincy Drip
	Dry matter (%)			
135-202	12.1	11.3NS[z]	15.7	22.6*
270-404	10.9	11.1NS	14.5	17.9NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

irrigation. Rate of N-K did not affect dry matter percentage at either location with either method of irrigation. Fresh and dry weights of tomato plants were higher with fall + spring N-K application but dry matter percentage was higher with fall than with fall + spring fertilization (Table 4-61). The number of plants·ha^{-1} was not affected by time of nutrient application. Location and time interacted in their effects on tomato plant fresh and dry weights (Table 4-63). Fresh and dry weights were higher with fall + spring than fall application time at both locations but the rate of increase in fresh and dry weights was greater at Gainesville than at Quincy.

Gainesville Soil Analyses

At Gainesville, pH was higher with drip than with overhead irrigation and decreased with an increase in N-K rate (Table 4-64). Soil pH was higher with fall than fall + spring fertilization and at the center than at the side of the bed (Table 4-64), but location and irrigation method interacted in their effect on pH (Table 4-65). At the center of the bed, pH was higher with drip than with overhead irrigation but at the side, irrigation method did not influence pH. With overhead irrigation, pH was similar at both locations but with drip irrigation, soil pH was higher at the center than at the side of the bed. With an increase in depth of sampling, soil pH decreased (Table 4-64) but irrigation method, N-K rate, time and depth interacted in their effect on pH (Table 4-66). Soil pH decreased linearly with an increase in depth with all treatment combinations except with overhead irrigation and fall applied N-K at the higher rate when the response was quadratic. Rate of N-K did not affect pH

Table 4-63. Tomato plant fresh and dry weights as affected by location x time interaction.

Time	Fresh wt (kg)		Dry wt (g)	
	Gainesville	Quincy	Gainesville	Quincy
Fall	1.09	0.54	125	86
Fall + spring	2.39	0.95	265	140
	***[z]	**	***	**

[z] Effects were significant at the 1% (**) or 0.1% (***) level.

Table 4-64. Soil chemical characteristics after tomato at Gainesville as affected by irrigation method, N-K rate, application time, bed location and soil depth.

Treatment	pH	Ec ($dS \cdot m^{-1}$)	Soil concn (ppm) NO_3-N	NH_4-N	P	K	Ca	Mg
Irrigation (I)								
Overhead	6.45	1.52	5.23	1.55	1.03	17.9	15.1	2.41
Drip	6.60	0.77	1.42	0.34	1.34	6.71	7.41	1.27
Significance[z]	*	*	***	NS	*	NS	*	*
N-K rate (R) ($kg \cdot ha^{-1}$)								
135-202	6.60	0.86	1.93	0.37	1.22	6.41	9.12	1.57
270-404	6.45	1.44	4.72	1.52	1.15	18.2	13.4	2.11
Significance	***	***	***	*	NS	***	*	*
Time (T)								
Fall	6.60	1.05	2.68	0.62	1.25	9.54	11.1	1.84
Fall + spring	6.44	1.25	3.97	1.27	1.11	15.1	11.4	1.84
Significance	***	NS	NS	NS	*	**	NS	NS
RxT	***	NS	NS	NS	***	*	NS	NS
IxRxT	**	*	NS	NS	**	NS	NS	*
Location (L)								
Center	6.55	1.28	3.79	1.51	1.39	16.0	11.1	1.95
Side	6.49	1.01	2.86	0.38	0.98	8.69	11.4	1.73
Significance	*	NS	NS	*	***	***	NS	NS
IxL	***	**	NS	*	NS	***	NS	NS
IxRxL	NS	NS	NS	*	NS	**	NS	NS
TxL	NS	NS	NS	NS	NS	NS	**	*
TxTxL	NS	NS	NS	NS	NS	NS	*	NS
Depth (D) (cm)								
0-10	6.74	1.78	6.73	1.93	1.47	19.2	19.6	3.27
10-20	6.61	0.89	1.75	0.60	1.14	9.40	8.02	1.31
20-30	6.22	0.77	1.50	0.30	0.94	8.39	6.13	0.95
Significance	***	***	***	**	***	***	***	***
RxD	NS	*	**	*	NS	*	NS	*
IxRxD	NS	*	***	NS	NS	*	*	*
IxRxTxD	*	NS	NS	NS	NS	NS	NS	NS
IxLxD	NS	*	NS	*	NS	*	NS	NS
TxLxD	NS	NS	NS	NS	*	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-65. Soil pH as affected by irrigation method x bed location interaction.

Irrigation	pH	
	Center	Side
Overhead	6.41	6.48NS[z]
Drip	6.70	6.50**
	***	NS

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-66. Soil pH as affected by irrigation method x N-K rate x application time x soil depth interaction.

Time and depth (cm)	Overhead		Drip	
	135-202	270-404	135-202	270-404
		pH		
Fall				
0-10	6.61	6.71NS[z]	7.00	6.89NS
10-20	6.54	6.65NS	6.86	6.80NS
20-30	6.19	6.20NS	6.40	6.35NS
	L***	L***Q*	L***	L***
Fall + spring				
0-10	6.93	6.38***	6.74	6.64NS
10-20	6.67	6.20***	6.70	6.45*
20-30	6.19	6.08NS	6.32	6.03*
	L***	L**	L**	L***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

with fall application and overhead or drip irrigation at any depth sampled. With fall + spring nutrient application, at the 0-10 and 10-20 cm depths with overhead irrigation and the 10-20 and 20-30 cm depths with drip irrigation, pH decreased with an increase in N-K rate but at the 20-30 cm depth with overhead and the 0-10 cm depth with drip irrigation, N-K rate did not affect pH.

Soil EC was higher with overhead than with drip irrigation and increased with N-K rate, but was not affected by time of N-K application (Table 4-64). Irrigation method, N-K rate and time interacted in their effect on EC (Table 4-67). With fall applied N-K at either rate or with fall + spring application with the lower rate, irrigation method did not affect EC but with fall + spring applied N-K at the higher rate, EC was higher with overhead than with drip irrigation. With either irrigation method and fall nutrient application, or with drip irrigation and fall + spring time of fertilization, N-K rate did not affect soil EC. However, EC increased with N-K rate with fall + spring fertilization and overhead irrigation. Soil EC values were similar at the center and side of the bed, and decreased with increased depth (Table 4-64) but values were influenced by interactions between irrigation method, N-K rate and depth, and irrigation method, location and depth (Table 4-68). With overhead irrigation and the lower N-K rate, EC was similar at all depths but with overhead irrigation and the higher N-K rate, the response to increased depth was quadratic. With drip irrigation and both N-K rates, EC values decreased linearly with increased depth. With overhead irrigation, EC increased with an increase in N-K rate at

Table 4-67. Soil EC and P and Mg concentrations as affected by irrigation method x N-K rate x application time interaction.

Time and N-K rate ($kg \cdot ha^{-1}$)	EC ($dS \cdot m^{-1}$)		P (ppm)		Mg (ppm)	
	Overhead	Drip	Overhead	Drip	Overhead	Drip
Fall						
135-202	1.10	0.68NS	1.04	1.27NS	2.12	1.35NS
270-404	1.68	0.77NS	1.23	1.48NS	2.45	1.45NS
	NS	NS	NS	NS	NS	NS
Fall + spring						
135-202	0.85	0.80NS	1.26	1.31NS	1.47	1.34NS
270-404	2.52	0.83***	0.60	1.30***	3.60	0.96**
	***	NS	***	NS	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-68. Soil EC as affected by irrigation method x N-K rate x soil depth and irrigation method x bed location x soil depth interactions.

Irrigation method and depth (cm)	N-K rate ($kg \cdot ha^{-1}$)		Location	
	135-202	270-404	Center	Side
		EC ($dS \cdot m^{-1}$)		
Overhead				
0-10	1.47	3.70**[z]	3.36	1.81NS
10-20	0.76	1.41**	1.20	0.97NS
20-30	0.69	1.11*	1.00	0.80NS
	NS	L***Q*	L***Q*	NS
Drip				
0-10	0.93	1.01NS	0.82	1.12NS
10-20	0.69	0.72NS	0.70	0.70NS
20-30	0.60	0.67NS	0.62	0.66NS
	L**	L***	NS	L***Q*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

all depths, but with drip irrigation, rate of N-K did not affect soil EC at any depth. At the center of the bed with overhead irrigation and at the side with drip irrigation, the response to increasing depth of sample was quadratic but at the center with drip and at the side with overhead irrigation, EC values were similar at all depths (Table 4-68). Sample EC values were similar at the center and side of the bed with both irrigation methods at each depth of sampling.

Soil NO_3-N concentration was higher with overhead than drip irrigation and increased with increased N-K application (Table 4-64). Values were similar with fall or fall + spring fertilization and at the center or side of the bed. Concentration of NO_3-N decreased with an increased depth of sample but irrigation method, N-K rate and depth interacted in their effect on NO_3-N concentration (Table 4-69). With overhead irrigation and the lower N-K rate, and with drip irrigation and the higher rate, NO_3-N concentrations were similar at all depths sampled. With overhead irrigation at the higher rate, the response with an increase in soil depth was quadratic with the greatest rate of decrease between the 0-10 and 10-20 cm depths. With drip irrigation at the lower N-K rate, NO_3-N concentration decreased linearly with increasing depth. With overhead irrigation at the 0-10 cm depth of sampling, NO_3-N concentration was higher with the higher N-K rate but with overhead irrigation at the 10-20 and 20-30 cm depths or with drip irrigation at all sample depths, the concentration of NO_3-N was not affected by rate of N-K application.

At Gainesville, soil NH_4-N concentration was not influenced by irrigation method or time of application, but was higher with the

Table 4-69. Soil NO_3-N and K concentrations as affected by irrigation method x N-K rate x soil depth interaction.

Irrigation and depth (cm)	NO_3-N (ppm)		K (ppm)	
	135-202	270-404	135-202	270-404
Overhead				
0-10	3.79	18.6 **[z]	12.9	47.2**
10-20	1.86	3.02NS	5.71	20.5*
20-30	1.31	2.83NS	5.15	16.3*
	NS	L***Q**	NS	L***
Drip				
0-10	2.65	1.91NS	5.80	10.9*
10-20	1.12	1.01NS	4.19	7.26*
20-30	0.88	0.97NS	4.74	7.39*
	L**	NS	NS	L*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

higher N-K rate (Table 4-64). The concentration of NH_4-N was higher at the center than at the side of the bed but irrigation method, N-K rate and location interacted in their effect on soil NH_4-N concentration (Table 4-70). With overhead irrigation at both bed locations, NH_4-N concentration increased with N-K rate but with drip irrigation at either bed location, N-K rate did not affect soil NH_4-N concentration. Soil NH_4-N concentrations were similar at the center and side of the bed with all irrigation method and N-K rate treatment combinations. Soil NH_4-N concentration decreased with an increase in depth but values were influenced by interactions between N-K rate and depth (Table 4-71) and irrigation method, location and depth (Table 4-72). With the 135-202 $kg \cdot ha^{-1}$ N-K rate, NH_4-N concentration was similar at all depths but with the 270-404 rate, values decreased linearly with increased depth (Table 4-71). Rate of N-K application did not affect soil NH_4-N concentration at any depth of sampling. At the center of the bed with overhead irrigation, NH_4-N concentration decreased linearly with greater soil depth but at the side with overhead or at either location with drip irrigation, values were similar at all depths (Table 4-72). With both methods of irrigation at all depths, soil NH_4-N values were similar at the center and side of the bed.

Phosphorus concentration was higher with drip than with overhead irrigation but was not influenced by N-K rate (Table 4-64). Soil P concentration was higher with fall than with fall + spring nutrient application, but was influenced by an interaction between irrigation method, N-K rate and time of application (Table 4-67). With fall

Table 4-70. Soil NH_4-N and K concentrations as affected by irrigation method x N-K rate x bed location interaction.

Irrigation and N-K rate ($kg \cdot ha^{-1}$)	NH_4-N (ppm)		K (ppm)	
	Center	Side	Center	Side
Overhead				
135-202	0.58	0.28NS[z]	10.8	5.0*
270-404	4.80	0.56NS	42.0	13.9**
	*	*	**	**
Drip				
135-202	0.30	0.34NS	3.68	6.15*
270-404	0.38	0.34NS	7.34	9.68NS
	NS	NS	**	*

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-71. Soil NH_4-N and K concentrations as affected by N-K rate x soil depth interaction.

Depth (cm)	NH_4-N (ppm)		K (ppm)	
	135-202	270-404	135-202	270-404
0-10	0.51	3.36NS[z]	9.35	29.0**
10-20	0.36	0.84NS	4.95	13.9**
20-30	0.25	0.35NS	4.95	11.8**
	NS	L**	NS	L***

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level. Effects of depth were linear (L).

Table 4-72. Soil NH_4-N and K concentrations as affected by irrigation method x bed location x soil depth interaction.

Irrigation and and depth (cm)	NH_4-N (ppm)		K (ppm)	
	Center	Side	Center	Side
Overhead				
0-10	6.35	0.59NS[z]	45.0	15.1 *
10-20	1.34	0.42NS	18.5	7.64NS
20-30	0.37	0.24NS	15.8	5.65*
	L**	NS	L**	NS
Drip				
0-10	0.38	0.41NS	4.95	11.7 **
10-20	0.34	0.31NS	5.20	6.26NS
20-30	0.30	0.30NS	6.38	5.75NS
	NS	NS	NS	L**

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level. Effects of depth were linear (L).

fertilization and either irrigation method or with fall + spring application and drip irrigation, soil P concentration was not affected by N-K rate but with fall + spring application and overhead irrigation, P concentration decreased with an increase in N-K rate. With fall applied N-K at either rate or with fall + spring fertilization at the lower N-K rate, P concentrations were similar with overhead or drip irrigation but with fall + spring N-K application at the higher rate, soil P concentration was lower with overhead than with drip irrigation. The concentration of P was higher at the center than the side of the bed and decreased with increased depth of sample (Table 4-64), but application time, location and depth of sample interacted in their effect on soil P (Table 4-73). With both times of nutrient application at the center of the bed, P concentration decreased linearly as soil depth increased but with either application time at the side of the bed, values were similar at all depths. With fall nutrient application at the 0-10 and the 10-20 cm depths, P concentration was higher at the center than at the side of the bed but at the 20-30 cm depth, values were similar at the 2 locations. With fall + spring fertilization, P concentrations were higher at the center than the side of the bed at all depths.

Potassium concentration was not affected by irrigation method but increased with N-K rate (Table 4-64). Soil K concentration was higher with fall + spring than with fall fertilization but N-K rate and time of application interacted in their effect on soil K (Table 4-74). With both application times, K concentration increased with N-K rate but the rate of increase was greater with fall + spring than with fall

Table 4-73. Soil P concentrations as affected by application time x bed location x soil depth interaction.

Depth (cm)	Fall		Fall + spring	
	Center	Side	Center	Side
		P (ppm)		
0-10	2.09	1.08***[z]	1.66	1.04*
10-20	1.38	1.06*	1.24	0.88*
20-30	0.89	1.02NS	1.07	0.80**
	L***	NS	L**	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-74. Soil K concentration as affected by N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	K (ppm)	
	Fall	Fall + spring
135-202	5.83	13.3NS[z]
270-404	7.00	23.2NS
	*	***

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

nutrient application. With either N-K rate, time of application did not affect soil K concentration. The K concentration was higher at the center than the side of the bed (Table 4-64) but was influenced by an interaction between location, irrigation method and N-K rate (Table 4-70). With all irrigation method-location combinations, K concentration increased with N-K rate. With overhead irrigation and both N-K rates, K concentration was higher at the center than the side of the bed, with the greater difference occurring at the higher rate. With drip irrigation and the lower N-K rate, the concentration of K was higher at the side than at the center, but with the higher N-K rate, values were similar at each location. Soil K concentration decreased with an increase in depth (Table 4-64) but irrigation method, N-K rate and depth (Table 4-69), and irrigation method, location and depth interacted in their effects on K concentration (Table 4-72). With both overhead and drip irrigation with the lower N-K rate, soil K concentrations were similar at each depth but with either irrigation method with the higher N-K rate, K concentration decreased linearly with increased depth (Table 4-69). The K concentration increased with N-K rate at all depths with both methods of irrigation (Table 4-72). Soil K concentration decreased linearly with increased soil depth with overhead irrigation at the center of the bed and with drip irrigation at the side. Depth did not influence K concentration with overhead irrigation at the side or with drip irrigation at the center of the bed. With overhead irrigation at the 0-10 and 20-30 cm depths, K concentration was higher at the center than the side of the bed, but with overhead at the 10-20 cm depth,

values were not affected by location. With drip irrigation at the 0-10 cm depth, K concentration was higher at the side than the bed center but did not vary with location at the greater soil depths.

Soil Ca concentration was higher with overhead than with drip irrigation and increased with N-K rate but was not affected by application time or bed location (Table 4-64). However, irrigation method, time and location interacted in their effect on sample Ca concentration (Table 4-75). With fall nutrient application and either irrigation method or with fall + spring fertilization and overhead irrigation, Ca values were not affected by location, but with fall + spring N-K application and drip irrigation, Ca concentration was lower at the center than at the side of the bed. At the center of the bed with either application time or at the side with fall + spring nutrient application, the concentration of Ca was higher with overhead than with drip irrigation. At the side of the bed with fall N-K application, values were similar with overhead or drip irrigation. The Ca concentration decreased with increased depth but was influenced by an interaction between irrigation method, N-K rate and depth (Table 4-76). With either irrigation method and the lower N-K rate, Ca concentration decreased linearly with increased soil depth. With overhead irrigation and the higher N-K rate, the response to greater depth was quadratic. Soil Ca concentration decreased significantly from the 0-10 to the 10-20 cm depth, but changed only slightly from 10-20 to 20-30 cm. With drip irrigation and the higher rate, values were similar at all depths. With overhead irrigation at the 0-10 cm depth, Ca concentration increased with N-K rate, but rate did not

Table 4-75. Soil Ca concentration as affected by irrigation method x application time x bed location interaction.

Location	Fall		Fall + spring	
	Overhead	Drip	Overhead	Drip
	Ca (ppm)			
Center	20.2	7.25*[z]	11.9	5.25*
Side	9.15	7.83NS	19.3	9.29**
	NS	NS	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-76. Soil Ca and Mg concentrations as affected by irrigation method x N-K rate x soil depth interaction.

Irrigation and depth (cm)	Ca (ppm)		Mg (ppm)	
	135-202	270-404	135-202	270-404
Overhead				
0-10	18.6	39.2 *[z]	3.11	6.38*
10-20	8.11	11.3 NS	1.31	1.53NS
20-30	5.58	7.90NS	0.96	1.17NS
	L*	L***Q*	L*	L***Q**
Drip				
0-10	10.9	9.83NS	1.86	1.71NS
10-20	6.62	6.06NS	1.29	1.11NS
20-30	4.97	6.09NS	0.88	0.78NS
	L**	NS	L***	L**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

affect Ca concentration at the greater depths with overhead irrigation, or at any depth with drip irrigation.

The concentration of Mg was higher with overhead than with drip irrigation and increased with N-K application rate but was not affected by time of application (Table 4-64). However, these treatments interacted in their effect on soil Mg concentration (Table 4-67). With fall fertilization and both N-K rates or with fall + spring application at the lower rate, irrigation method did not influence Mg concentration but with fall + spring applied N-K with the higher rate, soil Mg concentration was higher with overhead than with drip irrigation. Nutrient application rate did not affect soil Mg concentration with either irrigation method and fall time of application or with drip irrigation and fall + spring fertilization but with overhead irrigation and fall + spring nutrient application the Mg concentration increased with an increase in N-K rate. Soil Mg values were similar at the center and side of the bed (Table 4-64) but application time and bed location interacted in their effects on Mg concentration (Table 4-77). With fall or fall + spring fertilization, Mg concentrations were similar at the center and the side of the bed. At the center of the bed, time of application did not affect sample Mg concentration but at the side, the Mg concentration was higher with fall + spring fertilization than with fall nutrient application. Soil Mg concentration decreased with an increase in depth (Table 4-64) but values were influenced by an interaction between irrigation method, N-K rate and depth (Table 4-76). With overhead irrigation and the lower N-K rate or with drip irrigation and

Table 4-77. Soil Mg concentration as affected by application time x bed location interaction.

Time	Mg (ppm)	
	Center	Side
Fall	2.30	1.38NS[z]
Fall + spring	1.60	2.08NS
	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*) level.

either N-K rate, soil Mg concentration decreased linearly with an increase in depth. With overhead irrigation and the higher N-K rate, the response to increasing depth was quadratic. With overhead irrigation and 0-10 cm depth of sampling, Mg concentration was higher with the higher rate of N-K, but with overhead irrigation and the 2 lowest depths or with drip irrigation and all depths, N-K rate did not affect soil Mg concentration.

Quincy Soil Analyses

Soil pH was not affected by irrigation method, N-K rate or location but was lower with fall + spring than with fall nutrient application and decreased with increased soil depth (Table 4-78).

Electrical conductivity was not affected by irrigation method or N-K rate but was higher with fall + spring than fall fertilization (Table 4-78). However, these treatments interacted in their effect on soil EC (Table 4-79). With fall nutrient application and overhead irrigation, EC decreased with an increase in N-K rate but with fall applied N-K and drip irrigation, EC increased with N-K rate. With the fall applied lower N-K rate, EC was higher with overhead than with drip irrigation but with fall fertilization with the higher N-K rate or with fall + spring application with either rate, irrigation method did not affect EC. Soil EC was higher at the side than at the center of the bed but N-K rate, application time, and sample location interacted to influence EC (Table 4-80). With fall 135-202 $kg \cdot ha^{-1}$ N-K application, EC was higher at the side than the center of the bed but with fall application with the higher rate or with fall + spring fertilization with either N-K rate, EC values were similar at the

Table 4-78. Soil chemical characteristics after tomato at Quincy as affected by irrigation method, N-K rate, application time, bed location and soil depth.

Treatment	pH	Ec ($dS \cdot m^{-1}$)	Soil concn (ppm) NO_3-N	NH_4-N	P	K	Ca	Mg
Irrigation (I)								
Overhead	6.01	0.39	1.35	0.28	0.34	5.68	20.0	2.95
Drip	5.91	0.39	1.28	0.25	0.49	5.07	11.8	1.86
Significance[z]	NS	NS	NS	NS	NS	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)								
135-202	5.99	0.39	1.28	0.26	0.38	4.24	16.5	2.48
270-404	5.94	0.39	1.35	0.27	0.45	6.50	15.2	2.32
Significance	NS	NS	NS	NS	NS	***	NS	NS
Time (T)								
Fall	6.00	0.38	1.11	0.25	0.45	3.80	13.7	2.43
Fall + spring	5.93	0.40	1.52	0.28	0.38	6.95	18.0	2.37
Significance	*	*	***	NS	NS	***	NS	NS
IxRxT	NS	**	NS	NS	*	*	NS	*
Location (L)								
Center	5.97	0.38	1.15	0.27	0.44	5.71	16.7	2.51
Side	5.96	0.40	1.48	0.26	0.39	5.03	15.1	2.29
Significance	NS	*	**	NS	NS	*	NS	NS
RxTxL	NS	*	NS	*	NS	NS	NS	NS
Depth (D) (cm)								
0-10	6.00	0.39	1.31	0.30	0.71	5.55	18.6	2.54
10-20	5.98	0.37	1.20	0.25	0.38	4.57	13.2	2.06
20-30	5.91	0.41	1.44	0.24	0.17	6.00	15.8	2.61
Significance	*	Q**	NS	**	L***	Q*	NS	NS
IxRxTxD	NS	NS	NS	NS	NS	NS	**	NS
IxLxD	NS	NS	NS	*	NS	NS	NS	NS
RxTxLxD	NS	NS	NS	NS	NS	NS	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

Table 4-79. Soil EC and P, K and Mg concentrations as affected by irrigation method x N-K rate x application time interaction.

Time and N-K rate ($kg \cdot ha^{-1}$)	Irrigation		Irrigation	
	Overhead	Drip	Overhead	Drip
	EC ($dS \cdot m^{-1}$)		P (ppm)	
Fall				
135-202	0.40	0.36*[z]	0.39	0.47NS
270-404	0.36	0.39NS	0.29	0.67**
	*	*	NS	NS
Fall + spring				
135-202	0.39	0.40NS	0.29	0.39NS
270-404	0.40	0.40NS	0.39	0.45NS
	NS	NS	NS	NS
	K (ppm)		Mg (ppm)	
Fall				
135-202	4.23	2.54***	2.53	1.94NS
270-404	3.87	4.54NS	3.27	1.99NS
	NS	***	NS	NS
Fall + spring				
135-202	4.87	5.34NS	3.74	1.71**
270-404	9.73	7.88NS	2.25	1.79NS
	***	***	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-80. Soil EC and NH_4-N concentration as affected by N-K rate x application time x bed location interaction.

N-K rate ($kg \cdot ha^{-1}$) and time	EC ($dS \cdot m^{-1}$)		NH_4-N (ppm)	
	Center	Side	Center	Side
135-202				
Fall	0.36	0.40*[z]	0.27	0.24NS
Fall + spring	0.39	0.40NS	0.26	0.27NS
	*	NS	NS	NS
270-404				
Fall	0.38	0.37NS	0.22	0.27NS
Fall + spring	0.39	0.41NS	0.32	0.26NS
	NS	NS	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

center and side of the bed. With the lower N-K rate at the center of the bed, EC was higher with fall + spring than with fall fertilization but with the lower rate at the side or with the higher rate at either location, time of nutrient application did not influence EC values. With either fall or fall + spring fertilization and at either bed location, rate of N-K application did not affect soil EC (data not shown). The influence of depth on soil EC was quadratic (Table 4-76).

Soil NO_3-N concentration was not affected by irrigation method or N-K rate but was higher with fall + spring than fall nutrient application (Table 4-76). Soil NO_3-N concentration was higher at the side than the center of the bed, but values were similar at all depths of sampling.

Ammonium concentration was not influenced by irrigation method, rate of time of N-K application, or bed location, but rate and time of N-K application and location interacted in their effect on soil NH_4-N concentration (Table 4-80). With all N-K rate x time treatment combinations, NH_4-N concentrations were similar at the center and side of the bed. With the lower N-K rate at both bed locations and with the higher N-K rate at the side of the bed, soil NH_4-N concentration was not influenced by application time but with the higher rate at the center of the bed, NH_4-N concentration was higher with fall + spring than with fall fertilization. Rate of N-K application did not affect NH_4-N concentration at either bed location with fall or fall + spring fertilization (data not shown). Soil NH_4-N concentration decreased with an increase in depth but was influenced by an interaction between

irrigation method, location and depth of sampling (Table 4-81). With overhead irrigation at the center of the bed, NH_4-N concentration decreased linearly as depth increased but with drip at the center or with either method of irrigation at the side, values were similar at all depths. At the center of the bed at the 0-10 cm depth, NH_4-N concentration was higher with overhead than with drip irrigation but irrigation method did not affect soil NH_4-N concentration with any other location x depth treatment combination. Soil NH_4-N concentrations were similar at the center and the side of the bed with both irrigation methods and at all depths (data not shown).

At Quincy, soil P concentration was not affected by irrigation method or rate or time of N-K application, but these treatments interacted in their effect on P concentration (Table 4-79). With either fall or fall + spring fertilization and either irrigation method, N-K rate did not affect soil P concentration. With fall N-K application at the higher rate, soil P concentration was higher with drip than with overhead irrigation, but with fall fertilization with the lower rate or fall + spring application with either N-K rate, method of irrigation did not influence P concentration. Soil P values were similar at the center and side of the bed, but decreased linearly with increased depth (Table 4-78).

Potassium concentration was not influenced by irrigation method but was higher with the higher N-K rate (Table 4-78). Concentrations were higher with fall + spring than with fall fertilization but irrigation method and N-K rate and time interacted to affect soil K concentration (Table 4-79). With fall application time and overhead

Table 4-81. Soil NH_4-N and K concentrations as affected by irrigation method x bed location x soil depth interaction.

Location and depth (cm)	NH_4-N (ppm)		K (ppm)	
	Overhead	Drip	Overhead	Drip
Center				
0-10	0.39	0.23**[z]	6.31	5.58NS
10-20	0.25	0.27NS	5.66	4.48NS
20-30	0.22	0.24NS	6.17	6.08NS
	L**	NS	NS	NS
Side				
0-10	0.30	0.29NS	5.51	4.82NS
10-20	0.27	0.22NS	4.53	3.61NS
20-30	0.25	0.24NS	5.88	5.87NS
	NS	NS	NS	Q*

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level. Effects of depth were linear (L) or quadratic (Q).

irrigation, N-K rate did not affect soil K concentration but with fall application and drip irrigation and with fall + spring fertilization with either irrigation method, soil K concentration increased with an increase in N-K rate. With fall nutrient application with the lower N-K rate, soil K concentration was higher with overhead than with drip irrigation but with fall applied N-K with the higher rate or fall + spring fertilization with either rate, irrigation method did not influence K concentration. The concentration of K was higher at the center than at the side of the bed (Table 4-78). With an increase in soil depth, the K concentration response was variable.

Soil Ca concentration at Quincy was not affected by any treatment alone, but was influenced by an interaction between irrigation method, N-K rate, application time and depth of sampling (Table 4-82). With either time of application and overhead or drip irrigation with either rate of N-K, Ca concentrations were not affected by depth. With fall fertilization with the lower N-K rate at the 0-10 and 10-20 cm depths, and at all depths with fall application with the higher rate, Ca concentration was not affected by irrigation method. At the 20-30 cm depth with 135-202 $kg \cdot ha^{-1}$ N-K fall applied, Ca concentration was higher with overhead than with drip irrigation. With fall + spring fertilization with the lower N-K rate, and at the 0-10 and 20-30 cm depths, Ca concentrations were higher with overhead than with drip irrigation but at the 10-20 cm depth, values were similar with either irrigation method. With fall + spring nutrient application with the 270-404 $kg \cdot ha^{-1}$ rate and at the 10-20 cm depth, soil Ca concentration was higher with overhead than with drip but at the 0-10 and 20-30 cm

Table 4-82. Soil Ca concentration as affected by irrigation method x N-K rate x application time x soil depth interaction.

N-K rate ($kg \cdot ha^{-1}$) and depth (cm)	Fall		Fall + spring	
	Overhead	Drip	Overhead	Drip
		Ca (ppm)		
135-202				
0-10	9.05	17.4 NS[z]	40.1	10.4*
10-20	10.9	6.54NS	24.5	11.1NS
20-30	18.7	4.40**	27.7	15.2**
	NS	NS	NS	NS
270-404				
0-10	28.9	9.73NS	8.53	25.1 NS
10-20	20.2	8.29NS	16.9	6.91*
20-30	10.9	20.6 NS	22.6	5.68NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

depths, irrigation method did not influence Ca concentrations. With either application time with overhead or drip irrigation and at each depth, N-K rate did not affect Ca concentrations (data not shown).

The concentration of Mg was not affected by irrigation method, N-K rate or application time but was influenced by an interaction between these treatments (Table 4-79). With fall fertilization and overhead or drip irrigation or with fall + spring application and drip irrigation, N-K rate did not affect soil Mg concentration. However, with fall + spring nutrient application with overhead irrigation, the Mg concentration decreased with an increase in N-K rate. With fall application with either N-K rate or fall + spring fertilization with the higher rate, soil Mg values were similar with either irrigation method, but with fall + spring fertilization with the lower N-K rate, Mg concentration was higher with overhead than with drip irrigation. Soil Mg values were similar at the center and side of the bed and did not differ with depth, but rate, time, location and depth interacted in their effect on Mg concentration (Table 4-83). At the center of the bed with fall nutrient application with the lower N-K rate, Mg concentration decreased linearly with an increase in soil depth. Values were similar at all depths with all other rate x time x location treatment combinations. Rate of N-K application did not affect soil Mg concentration at any depth or location with either application time.

Soil Moisture

Soil moisture percentage at Gainesville was significantly higher with drip than with overhead irrigation and at the center than at the

Table 4-83. Soil Mg concentration as affected by N-K rate x application time x bed location x soil depth interaction.

Location and depth (cm)	Fall		Fall + spring	
	135-202	270-404	135-202	270-404
		Mg (ppm)		
Center				
0-10	3.89	4.60NS[z]	1.78	4.80NS
10-20	1.75	1.34NS	1.05	1.10NS
20-30	1.36	0.88NS	0.46	0.39NS
	L*	NS	NS	NS
Side				
0-10	1.64	2.95NS	2.65	3.83NS
10-20	0.95	1.11NS	1.44	1.73NS
20-30	0.80	0.84NS	1.04	1.79NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level. Effect of depth was linear (L).

side of the bed (Table 4-84). However, these variables interacted in their effect on soil moisture percentage (Table 4-85). At both the center and the side of the bed, soil moisture percentage was higher with drip than with overhead irrigation, but the difference was greater at the center. With either irrigation method, soil moisture percentage was higher at the center than at the side of the bed, but with drip irrigation the increase was greater than with overhead irrigation. Soil moisture percentage increased linearly with an increase in soil depth (Table 4-84). The response to time was quadratic but irrigation method and time interacted to influence soil moisture percentage (Table 4-86). With overhead irrigation, soil moisture percentage increased from day 1 to day 2 (following application of overhead irrigation) but decreased significantly from day 2 to day 3. With drip irrigation, values were similar at all 3 times of sampling. Soil moisture percentage was higher with drip than with overhead irrigation all 3 times of sampling.

1984 Squash Field Experiment

Yield

Early, late and total squash yields were not affected by location or irrigation method, but increased with an increase in N-K rate (Table 4-87). Early squash yield was higher with fall + spring than with residual fall nutrient application but location (Table 4-88), irrigation method (Table 4-89) and N-K rate (Table 4-90) each interacted with time of fertilization. With fall N-K application, early squash yields were similar at Gainesville and Quincy but with

Table 4-84. Soil moisture percentage as affected by irrigation method, bed location, depth and time at Gainesville.

Treatment	Soil moisture (%)
Irrigation (I)	
Overhead	5.66
Drip	7.31
Significance[z]	*
Location (L)	
Center	7.23
Side	5.74
Significance	***
IxL	***
Depth (cm)	
0-10	5.51
10-20	6.46
20-30	7.49
Significance	L***
Time (T) (day)	
1	6.34
2	6.60
3	6.52
Significance	NS
IxT	Q*

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level. Significant depth effect was linear (L). Significant time effect was quadratic (Q).

Table 4-85. Soil moisture percentage as affected by irrigation method x bed location interaction.

Irrigation	Soil moisture (%)	
	Center	Side
Overhead	5.94	5.38*[z]
Drip	8.53	6.10***
	***	*

[z] Effects were significant at the 5% (*) or 0.1% (***) level.

Table 4-86. Soil moisture percentage as affected by irrigation method x time interaction.

Time (day)	Soil moisture (%) Overhead	Drip
1	5.57	7.11**[z]
2	6.18	7.02***
3	5.23	7.81**
	Q*	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effect of time was quadratic (Q).

Table 4-87. Marketable yield of squash as affected by location, irrigation method, N-K rate and application time.

Treatment	Yield ($t \cdot ha^{-1}$) Early	Late	Total	No. fruit ($1000 \cdot ha^{-1}$)	Avg fruit wt (g)
Location (L)					
Gainesville	13.7	14.7	28.4	228	112
Quincy	11.7	11.4	25.1	223	105
Significance[z]	NS	NS	NS	NS	NS
Irrigation (I)					
Overhead	13.4	14.8	28.2	232	114
Drip	12.0	13.3	25.3	218	103
Significance	NS	NS	NS	NS	*
N-K rate (R) ($kg \cdot ha^{-1}$)					
135-202	11.4	12.1	23.5	206	98.4
270-404	14.0	16.0	30.0	244	118
Significance	**	***	***	***	***
LxIxR	NS	***	*	NS	*
Time (T)					
Fall	5.9	7.3	12.2	133	89.6
Fall + spring	19.5	20.8	40.3	317	126
Significance	***	**	***	***	***
LxT	*	**	**	NS	***
IxT	***	**	***	***	**
RxT	***	***	***	***	***
LxRxT	NS	*	NS	NS	NS
LxIxRxT	NS	NS	*	NS	***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-88. Early yield of squash as affected by location x application time interaction.

Time	Early yield ($t \cdot ha^{-1}$) Gainesville	Quincy
Fall	6.1	5.7NS[z]
Fall + spring	21.2	17.7*
	***	***

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-89. Early and late yield and number of squash fruit as affected by irrigation method x application time interaction.

Irrigation	Early yield ($t \cdot ha^{-1}$) Fall	Fall + spring	Late yield ($t \cdot ha^{-1}$) Fall	Fall + spring	No. ($1000 \cdot ha^{-1}$) Fall	Fall + spring
Overhead	8.0	18.7***[z]	9.1	20.4***	159	307***
Drip	3.8	20.2***	5.5	21.1***	108	328***
	**	NS	*	NS	**	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-90. Early yield and number of squash fruit as affected by N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Early yield ($t \cdot ha^{-1}$) Fall	Fall + spring	No. ($1000 \cdot ha^{-1}$) Fall	Fall + spring
135-202	3.1	19.8***[z]	94.6	318***
270-404	8.7	19.1***	172	316***
	***	NS	***	NS

[z] Effects were not significant (NS) or significant at the 0.1% (***) level.

fall + spring fertilization, yields were higher at Gainesville than Quincy (Table 4-88). With either method of irrigation, early yields were higher with fall + spring than with fall nutrient application (Table 4-89). With fall applied N-K, squash yields were higher with overhead than with drip irrigation but with fall + spring fertilizer application, yields were similar with either irrigation method. With both N-K rates, early yield was higher with fall + spring than fall fertilization (Table 4-90). With fall nutrient application, yield increased with an increase in N-K rate but with fall + spring time of application, N-K rate did not influence early squash yield.

Location, irrigation method and N-K rate combined to affect late yield (Table 4-91). At Gainesville with overhead irrigation, late squash yield increased with N-K rate but with drip irrigation or at Quincy with either irrigation method, N-K rate did not influence late yield of squash. At Gainesville and at Quincy with either rate of N-K, late yields were similar with overhead or drip irrigation. Late squash yield was higher with fall + spring than with fall nutrient application but location, N-K rate and time interacted in their effect on late yield (Table 4-92). At Gainesville with either time of N-K application and at Quincy with fall fertilization, late squash yield increased with an increase in N-K rate but at Quincy with fall + spring fertilization, yields were similar with either rate of N-K.

Total yield of squash was higher with the fall + spring than with the fall time of application, but location, irrigation method, N-K rate and time interacted to affect total squash yield (Table 4-93). At Gainesville with overhead irrigation and both times of

Table 4-91. Late yield of squash fruit as affected by location x irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Overhead	Drip	Overhead	Drip
		Late yield ($t \cdot ha^{-1}$)		
135-202	11.3	12.5NS[z]	13.6	11.0NS
270-404	19.0	15.9NS	15.2	13.8NS
	*	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-92. Late yield of squash as affected by location x N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
		Late yield ($t \cdot ha^{-1}$)		
135-202	3.9	19.9***[z]	4.5	20.1***
270-404	10.3	24.6***	10.6	18.5***
	***	**	**	NS

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-93. Total yield and average fruit weight of squash as affected by location x irrigation method x N-K rate x application time interaction.

Location, irrigation, and N-K rate ($kg \cdot ha^{-1}$)	Total yield ($t \cdot ha^{-1}$)		Avg fruit wt (g)	
	Fall	Fall + spring	Fall	Fall + spring
Gainesville				
Overhead				
135-202	6.0	38.1***[z]	69.0	133***
270-404	28.5	45.0**	128	140NS
	***	*	***	NS
Drip				
135-202	6.0	42.6***	67.2	127***
270-404	12.3	48.1***	86.7	141***
	**	NS	**	NS
Quincy				
Overhead				
135-202	13.2	38.6***	91.3	118**
270-404	20.8	34.8**	110	120NS
	NS	NS	*	NS
Drip				
135-202	3.7	39.7***	59.9	123***
270-404	15.1	34.7*	105	109NS
	**	NS	**	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

fertilization and with drip irrigation with fall N-K application, total yield increased with N-K rate but with drip irrigation and fall + spring fertilization, total yields were similar with either N-K rate. At Quincy with drip irrigation and fall fertilization, yield increased with an increase in N-K rate but N-K rate did not influence total yield with any other irrigation method-application time combination.

The number of fruit·ha^{-1} was not influenced by location or irrigation method but increased with N-K rate (Table 4-87). The number of fruit was higher with fall + spring than fall fertilization but irrigation method (Table 4-89) and N-K rate (Table 4-90) each interacted with time of application to affect fruit number. With fall N-K application, fruit number was higher with overhead than with drip irrigation but with fall + spring application, the number of fruit was similar with overhead or drip irrigation (Table 4-89). With fall nutrient application, fruit number increased with N-K rate but with fall + spring fertilization, N-K rate did not influence the number of fruit·ha^{-1} (Table 4-90). With both N-K application rates, the number of fruit was higher with fall + spring than with fall fertilization.

Average squash fruit weights were similar at both locations but were higher with overhead than drip irrigation (Table 4-87). Fruit weight increased with N-K rate and was higher with fall + spring than with fall N-K application but all treatments interacted to affect average fruit weight (Table 4-93). With fall nutrient application at both locations and with each irrigation method, average fruit weight

increased with N-K rate but with fall + spring fertilization at both locations with either irrigation method, N-K rate did not affect fruit weight.

Tissue Analyses

Six weeks after emergence, squash leaf N concentration was higher at Quincy than at Gainesville but values were similar at both locations for all other samples (Table 4-94). Leaf, 2nd fruit and plant N concentrations were not influenced by irrigation method but the first fruit sample (6 weeks after emergence) N concentration was higher with overhead than with drip irrigation. Leaf N concentration was not affected by N-K rate but was influenced by an interaction between location and N-K rate (Table 4-95). At both locations, N-K rate did not affect squash leaf N concentration. With the lower N-K rate, values were similar at each location but with the higher rate, leaf N concentration was 3.85% at Quincy and 2.52% at Gainesville. Rate of N-K application did not affect the N concentration of either fruit sample but plant N concentration increased with N-K rate (Table 4-94). However, location (Table 4-95) and irrigation method (Table 4-96) each interacted with N-K rate to affect plant N concentration. At Gainesville, N-K rate did not influence plant N concentration but at Quincy, plant N concentration was higher with the higher N-K rate (Table 4-95). With N-K applied at the lower rate, the plant N concentration was higher with overhead than with drip irrigation but with the higher N-K rate, values were similar with the 2 irrigation methods (Table 4-96). Tissue N concentration was higher with fall +

Table 4-94. Nitrogen concentration of squash as affected by location, irrigation method, N-K rate and application time.

Treatment	N concn (%)			
	Leaf	Fruit 1[z]	Fruit 2	Plant
Location (L)				
Gainesville	2.63	2.53	2.40	1.91
Quincy	3.58	2.57	2.50	2.14
Significance[y]	*	NS	NS	NS
Irrigation (I)				
Overhead	3.18	2.82	2.57	2.09
Drip	3.03	2.28	2.32	1.97
Significance	NS	**	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	3.02	2.47	2.42	1.72
270-404	3.19	2.63	2.47	2.33
Significance	NS	NS	NS	***
LxR	*	NS	NS	**
IxR	NS	NS	NS	*
Time (T)				
Fall	2.43	2.19	2.21	1.83
Fall + spring	3.77	2.91	2.69	2.22
Significance	***	***	**	***
LxT	***	NS	NS	NS
RxT	NS	NS	NS	***

[z] Fruit 1 and 2 samples taken at 6 and 10 weeks after emergence.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-95. Squash leaf and plant N concentrations as affected by location x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Leaf		Plant	
	Gainesville	Quincy	Gainesville	Quincy
	N concn (%)			
135-202	2.73	3.30NS[z]	1.75	1.69NS
270-404	2.52	3.85**	2.07	2.59*
	NS	NS	NS	***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-96. Squash plant N concentration as affected by irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	N concn (%)	
	Overhead	Drip
135-202	1.87	1.57**[z]
270-404	2.30	2.36NS
	*	***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

spring than with fall nutrient application at all times of sampling (Table 4-94). However, location (Table 4-97) and N-K rate (Table 4-98) interacted with time to influence the N concentration of leaf and plant samples, respectively. At both locations, leaf N concentration increased with N-K rate, but the rate of increase was greater at Quincy than at Gainesville (Table 4-97). With fall nutrient application, squash plant N values were similar with either N-K rate but with fall + spring fertilization plant N concentration increased with an increase in N-K rate (Table 4-98).

Leaf and fruit P concentrations 6 weeks after emergence were similar at Gainesville and Quincy but later fruit and plant tissue P concentrations were higher at Gainesville than at Quincy (Table 4-99). The concentration of P in leaf, first fruit and plant samples was not affected by irrigation method but 10 weeks after emergence, fruit P concentration was higher with drip than with overhead irrigation. Tissue P concentration decreased with an increase in N-K rate with all tissue samples except fruit 6 weeks after emergence. The concentration of P in all tissue samples was higher with fall than with fall + spring time of nutrient application, but was influenced also by several interactions with time of fertilization. Leaf P concentration at Gainesville with drip irrigation and at Quincy with overhead irrigation was higher with fall than with fall + spring N-K application (Table 4-100). However, at Quincy with drip irrigation, the opposite response to application time was observed. At Gainesville with either application time and at Quincy with fall fertilization, P concentration of fruit at the 2nd time of sampling

Table 4-97. Squash leaf N concentration as affected by location x application time interaction.

Time	N concn (%)	
	Gainesville	Quincy
Fall	2.25	2.61
Fall + spring	3.00	4.54
	***[z]	***

[z] Effects were significant at the 0.1% (***) level.

Table 4-98. Squash plant N concentration as affected by N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	N concn (%)	
	Fall	Fall + spring
135-202	1.71	1.96NS[z]
270-404	1.73	2.70***
	NS	***

[z] Effects were not significant (NS) or significant at the 0.1% (***) level.

Table 4-99. Phosphorus concentration of squash as affected by location, irrigation method, N-K rate and application time.

Treatment	P concn (%)			
	Leaf	Fruit 1[z]	Fruit 2	Plant
Location (L)				
Gainesville	0.59	1.02	0.97	0.68
Quincy	0.60	0.98	0.66	0.50
Significance[y]	NS	NS	**	***
Irrigation (I)				
Overhead	0.57	0.98	0.78	0.53
Drip	0.62	1.03	0.85	0.65
Significance	NS	NS	*	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	0.63	1.03	0.86	0.67
270-404	0.56	0.98	0.77	0.51
Significance	*	NS	***	***
Time (T)				
Fall	0.65	1.09	0.88	0.72
Fall + spring	0.54	0.91	0.74	0.46
Significance	***	***	***	***
LxT	*	NS	**	**
LxIxT	*	NS	**	NS
RxT	NS	NS	*	**

[z] Fruit 1 and 2 samples taken at 6 and 10 weeks after emergence.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-100. Squash leaf and fruit P concentrations 6 and 10 weeks after emergence as affected by location x irrigation method x application time interaction.

Location and irrigation	Leaf		Plant	
	Fall	Fall + spring	Fall	Fall + spring
	P concn (%)			
Gainesville				
Overhead	0.60	0.45NS[z]	0.94	0.95NS
Drip	0.76	0.55**	1.06	0.92*
	NS	NS	NS	NS
Quincy				
Overhead	0.68	0.56*	0.75	0.48***
Drip	0.53	0.63*	0.78	0.63NS
	**	NS	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

was not affected by irrigation method but at Quincy with fall + spring nutrient application, fruit P was higher with drip than with overhead irrigation. With fall application, fruit and plant P concentrations decreased with an increase in N-K rate but with fall + spring fertilization, values were similar with both rates (Table 4-101). At both locations, plant P concentration was higher with fall than with fall + spring fertilization (Table 4-102).

Leaf and fruit K concentrations 6 weeks after emergence were similar at Gainesville and at Quincy (Table 4-103). Ten weeks after emergence, fruit K concentration was higher at Gainesville than Quincy but plant K concentration was higher at Quincy than at Gainesville. Irrigation method did not affect K concentration of any tissue sampled but location and irrigation method interacted to influence fruit K concentration 6 weeks after emergence (Table 4-104). At Gainesville, fruit K concentrations were similar with either irrigation method but at Quincy, the K concentration of fruit was higher with overhead than with drip irrigation. Tissue K concentration increased with N-K rate with leaf, early fruit and whole plant samples but was higher with the lower N-K rate with fruit sampled 10 weeks after emergence (Table 4-103). Squash leaf and plant K concentrations were higher with fall + spring than with fall fertilization. However, early fruit K concentration was not influenced by time of nutrient application and later fruit K concentration was higher with fall than with fall + spring N-K application. Location, irrigation method, N-K rate and time interacted in their effect on K concentration of fruit at the 2nd sampling time (Table 4-105). At Gainesville with fall nutrient

Table 4-101. Squash fruit and plant P concentrations 10 weeks after emergence as affected by N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Fruit 2		Plant	
	Fall	Fall + spring	Fall	Fall + spring
		P concn (%)		
135-202	0.95	0.76**[z]	0.84	0.50***
270-404	0.82	0.73NS	0.60	0.42**
	*	NS	***	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-102. Squash plant P concentration as affected by location x application time interaction.

Time	P concn (%)	
	Gainesville	Quincy
Fall	0.78	0.66
Fall + spring	0.59	0.32
	**[z]	***

[z] Effects were significant at the 1% (**) or 0.1% (***) level.

Table 4-103. Potassium concentration of squash as affected by location, irrigation method, N-K rate and application time.

Treatment	K concn (%)			
	Leaf	Fruit 1[z]	Fruit 2	Plant
Location (L)				
Gainesville	4.69	5.00	4.45	3.80
Quincy	4.66	4.89	3.60	4.24
Significance[y]	NS	NS	**	*
Irrigation (I)				
Overhead	4.72	5.08	4.02	4.04
Drip	4.63	4.80	4.02	3.99
Significance	NS	NS	NS	NS
LxI	NS	*	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	4.46	4.72	4.13	3.72
270-404	4.89	5.17	3.92	4.32
Significance	*	***	*	***
Time (T)				
Fall	4.14	4.86	4.28	3.42
Fall + spring	5.21	5.02	3.76	4.62
Significance	***	NS	***	***
LxIxT	NS	NS	*	*
RxT	NS	NS	*	*
LxIxRxT	NS	NS	*	NS

[z] Fruit 1 and 2 samples taken at 6 and 10 weeks after emergence.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-104. Squash fruit K concentration 6 weeks after emergence as affected by location x irrigation method interaction.

Irrigation	K concn (%)	
	Gainesville	Quincy
Overhead	4.96	5.21
Drip	5.03	4.57
	NS[z]	***

[z] Effects were not significant (NS) or significant at the 0.1% (***) level.

Table 4-105. Squash fruit K concentration 10 weeks after emergence as affected by location x irrigation method x N-K rate x application time interaction.

Irrigation and N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
			K conen (%)	
Overhead				
135-202	5.14	4.13**[z]	3.94	3.15*
270-404	4.28	4.40NS	3.79	3.36NS
	*	NS	NS	NS
Drip				
135-202	4.78	4.09*	4.11	3.65NS
270-404	4.85	3.93*	3.39	3.39NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

application and overhead irrigation, fruit K concentration decreased with an increase in N-K rate but rate of N-K did not affect fruit K concentration with any other location-irrigation method-application time treatment combination. Plant K concentration was influenced by interactions between location, irrigation method and time (Table 4-106), and N-K rate and time (Table 4-107). At Gainesville with either time and at Quincy with fall + spring timing, irrigation method did not affect plant K concentration, but at Quincy with fall nutrient application, values were higher with overhead than with drip irrigation (Table 4-106). With either N-K rate, plant K concentration was higher with fall + spring than with fall fertilization (Table 4-107). Rate of N-K did not influence plant K concentration with fall application; however with fall + spring fertilization, plant K concentration increased with N-K rate.

Leaf and fruit tissue Ca concentrations 6 weeks after emergence were higher at Gainesville than at Quincy but later fruit and whole plant values were similar at the 2 locations (Table 4-108). Leaf Ca concentration was higher with drip than with overhead irrigation but irrigation method did not influence other tissue sample Ca concentrations. Rate of N-K application did not affect leaf or early fruit Ca concentrations but location and N-K rate interacted in their effect on fruit Ca concentration 6 weeks after emergence (Table 4-109). At Gainesville, fruit Ca concentration decreased with an increase in N-K rate but at Quincy, values were similar with either rate. The concentrations of Ca in later fruit and plant tissues were higher with the lower N-K rate (Table 4-108). Time of N-K application

Table 4-106. Squash plant K concentration as affected by location x irrigation method x application time interaction.

Irrigation	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
		K concn (%)		
Overhead	3.08	4.47**[z]	4.10	4.52NS
Drip	3.23	4.41**	3.26	5.08***
	NS	NS	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-107. Squash plant K concentration as affected by N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	K concn (%)	
	Fall	Fall + spring
135-202	3.39	4.04**[z]
270-404	3.44	5.20***
	NS	***

[z] Effects were not significant (NS) or significant at the 1% (*) or 0.1% (***) level.

Table 4-108. Calcium concentration of squash as affected by location, irrigation method, N-K rate and application time.

Treatment	Ca concn (%)			
	Leaf	Fruit 1[z]	Fruit 2	Plant
Location (L)				
Gainesville	3.08	0.36	0.37	4.15
Quincy	1.80	0.29	0.33	3.69
Significance[y]	**	***	NS	NS
Irrigation (I)				
Overhead	2.26	0.33	0.36	4.00
Drip	2.61	0.32	0.34	3.85
Significance	**	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	2.50	0.33	0.37	4.19
270-404	2.37	0.32	0.33	3.65
Significance	NS	NS	**	**
LxR	NS	**	NS	NS
Time (T)				
Fall	2.49	0.31	0.40	4.01
Fall + spring	2.38	0.34	0.30	3.83
Significance	NS	*	***	NS
IxT	NS	*	***	NS
LxIxT	*	NS	NS	NS
RxT	NS	NS	NS	**

[z] Fruit 1 and 2 samples taken at 6 and 10 weeks after emergence.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-109. Squash fruit Ca concentration 6 weeks after emergence as affected by location x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Ca concn (%)	
	Gainesville	Quincy
135-202	0.38	0.28
270-404	0.34	0.30
	*[z]	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

did not affect leaf Ca concentration but location, irrigation method and time interacted in their effect on leaf Ca (Table 4-110). At Gainesville with fall application and at Quincy with fall + spring fertilization, leaf Ca concentration was higher with drip than with overhead irrigation. However, at Gainesville with fall + spring nutrient application or at Quincy with fall fertilization, method of irrigation did not influence leaf Ca concentration. Six weeks after emergence, fruit Ca concentration was higher with fall + spring than fall fertilizer application, but irrigation method interacted with time to influence fruit Ca values (Table 4-111). With fall fertilization, early fruit Ca concentration was higher with overhead than with drip irrigation, but with fall + spring time of fertilization, values were similar with both irrigation methods. With overhead irrigation, time of N-K application did not influence early fruit Ca concentration but with drip irrigation, Ca concentration was higher with fall + spring than with fall fertilization. Ten weeks after emergence, fruit Ca concentration was higher with fall than fall + spring nutrient application but again, irrigation method interacted with time to influence fruit Ca concentration (Table 4-111). With fall nutrient application, irrigation method did not affect fruit Ca concentration but with fall + spring fertilization, the concentration was higher with overhead than with drip irrigation. Plant tissue Ca concentration was not affected by time of N-K application but N-K rate and time interacted in their effect on plant Ca concentration (Table 4-112). Rate of fall applied N-K did not influence plant Ca

Table 4-110. Squash leaf Ca concentration as affected by location x irrigation method x application time interaction.

Irrigation	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
		Ca concn (%)		
Overhead	2.54	3.25NS[z]	1.96	1.31***
Drip	3.30	3.22NS	2.17	1.77*
	*	NS	NS	***

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-111. Squash fruit Ca concentration 6 and 10 weeks after emergence as affected by irrigation method x application time interaction.

Irrigation	Fruit 1		Fruit 2	
	Fall	Fall + spring	Fall	Fall + spring
		Ca concn (%)		
Overhead	0.33	0.33NS[z]	0.38	0.33*
Drip	0.29	0.34**	0.41	0.27***
	*	NS	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-112. Squash plant Ca concentration as affected by N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Ca concn (%)	
	Fall	Fall + spring
135-202	4.00	4.38NS[z]
270-404	4.02	3.29**
	NS	***

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

concentration but with fall + spring application, plant Ca concentration decreased with an increase in N-K rate.

Six weeks after emergence, squash leaf Mg concentration was higher at Quincy than at Gainesville but fruit Mg was higher at the Gainesville location (Table 4-113). The Mg concentration of fruit sampled 10 weeks after emergence was not affected by location but plant Mg concentration was higher at Quincy than at Gainesville. Leaf Mg concentration was higher with drip than overhead irrigation but irrigation method did not influence tissue Mg concentration of either fruit or plant samples. Leaf Mg concentration decreased with an increase in N-K rate but the Mg concentration of fruit sampled at the same time was similar with either application rate. Tissue Mg concentration of later fruit and plant samples was higher with the lower N-K rate, but location and N-K rate interacted in their influence on Mg concentrations (Table 4-114). At Gainesville, fruit and plant Mg concentrations were not affected by N-K rate but at Quincy, concentrations decreased with an increase in N-K rate. With either nutrient rate, plant Mg concentration was higher at Quincy than at Gainesville. With all squash samples, tissue Mg concentration was higher with fall than with fall + spring nutrient application but all sample concentrations were influenced by interactions with time of fertilization. At Gainesville with either application time and at Quincy with fall fertilization, squash leaf Mg concentration was not influenced by irrigation method but at Quincy with fall + spring nutrient application, leaf Mg concentration was higher with drip than with overhead irrigation (Table 4-115). At Gainesville and Quincy

Table 4-113. Magnesium concentration of squash as affected by location, irrigation method, N-K rate and application time.

Treatment	Mg concn (%)			
	Leaf	Fruit 1[z]	Fruit 2	Plant
Location (L)				
Gainesville	0.67	0.31	0.39	0.95
Quincy	0.81	0.30	0.36	1.39
Significance[y]	*	*	NS	**
Irrigation (I)				
Overhead	0.68	0.31	0.38	1.20
Drip	0.80	0.30	0.37	1.14
Significance	**	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)				
135-202	0.79	0.31	0.39	1.26
270-404	0.69	0.30	0.36	1.08
Significance	**	NS	**	**
LxR	NS	NS	*	*
Time (T)				
Fall	0.83	0.32	0.39	1.23
Fall + spring	0.65	0.29	0.36	1.11
Significance	***	***	**	**
LxT	NS	NS	*	NS
LxIxT	*	NS	NS	NS
RxT	NS	*	NS	*
LxRxT	NS	*	NS	NS

[z] Fruit 1 and 2 samples taken at 6 and 10 weeks after emergence.
[y] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-114. Squash fruit and plant Mg concentrations 10 weeks after emergence as affected by location x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Fruit		Plant	
	Gainesville	Quincy	Gainesville	Quincy
	Mg concn (%)			
135-202	0.39	0.38	0.99	1.54***[z]
270-404	0.38	0.34	0.93	1.23**
	NS	**	NS	**

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-115. Squash leaf Mg concentration as affected by location x irrigation method x application time interaction.

Irrigation	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
		Mg conon (%)		
Overhead	0.65	0.58NS[z]	0.89	0.59***
Drip	0.83	0.63**	0.94	0.80*
	NS	NS	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

with the 135-202 $kg \cdot ha^{-1}$ N-K rate, fruit Mg values were similar with fall or fall + spring fertilization but at each location with the higher N-K rate, fruit Mg concentration was higher with fall than with fall + spring application (Table 4-116). At Quincy fruit Mg concentration 10 weeks after emergence was higher with fall than with fall + spring fertilization, but at Gainesville values were similar with either application time (Table 4-117). With fall fertilization, N-K rate did not influence squash plant Mg concentration but with fall + spring application, plant Mg concentration decreased with an increase in N-K rate (Table 4-118).

Squash fruit dry matter percentage 10 weeks after emergence was higher at Gainesville than at Quincy and with fall + spring than with fall fertilizer application but was not affected by irrigation method or N-K rate (Table 4-119).

Plant fresh and dry weights were higher at Gainesville than at Quincy but were not affected by irrigation method. Both plant fresh and dry weights increased with N-K rate and were higher with fall + spring than with fall nutrient application but all treatment variables interacted to affect plant fresh (Table 4-120) and dry weights (Table 4-121). At Gainesville, with fall nutrient application with either irrigation method, and with fall + spring fertilization with drip irrigation, fresh weight increased with an increase in N-K rate, but with fall + spring application with overhead irrigation, N-K rate did not affect squash plant fresh weight (Table 4-120). At Quincy, with fall nutrient application with drip irrigation, plant fresh weight

Table 4-116. Squash fruit Mg concentration 6 weeks after emergence as affected by location x N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
	Mg concn (%)			
135-202	0.31	0.31NS[z]	0.32	0.29NS
270-404	0.34	0.28**	0.31	0.28***
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-117. Squash fruit Mg concentration 10 weeks after emergence as affected by location x application time interaction.

Time	Mg concn (%)	
	Gainesville	Quincy
Fall	0.39	0.39
Fall + spring	0.38	0.34
	NS[z]	**

[z] Effects were not significant (NS) or significant at the 1% (**) level.

Table 4-118. Squash plant Mg concentration as affected by N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Mg concn (%)	
	Fall	Fall + spring
135-202	1.25	1.26NS[z]
270-404	1.20	0.95*
	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-119. Squash fruit dry matter percentage and plant fresh and dry weights, dry matter percentage and number as affected by location, irrigation method, N-K rate and application time.

Treatment	Fruit dry matter (%)	Plant			
		Fresh wt (kg)	Dry wt (g)	Dry matter (%)	No. ($1000 \cdot ha^{-1}$)
Location (L)					
Gainesville	6.70	1.34	104	8.54	33.5
Quincy	5.16	1.05	75.9	7.62	25.3
Significance[z]	*	*	**	*	**
Irrigation (I)					
Overhead	6.15	1.28	95.7	7.66	28.3
Drip	5.71	1.11	84.3	8.50	30.5
Significance	NS	NS	NS	*	*
N-K rate (R) ($kg \cdot ha^{-1}$)					
135-202	5.66	0.94	75.1	8.63	30.2
270-404	6.20	1.45	105	7.53	28.7
Significance	NS	***	***	***	*
IxR	NS	NS	NS	*	NS
LxIxR	NS	NS	NS	NS	**
Time (T)					
Fall	5.34	0.66	54.6	8.68	29.2
Fall + spring	6.52	1.74	125	7.48	29.6
Significance	**	***	***	***	NS
LxIxT	NS	*	**	*	NS
LxRxT	NS	NS	NS	**	**
LxIxRxT	NS	***	**	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-120. Squash plant fresh weight as affected by location x irrigation method x N-K rate x application time interaction.

Irrigation and N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
		Fresh wt (kg)		
Overhead				
135-202	0.32	1.66***[z]	0.63	1.63**
270-404	1.51	2.01NS	0.92	1.60*
	**	NS	NS	NS
Drip				
135-202	0.29	1.41**	0.18	1.38***
270-404	0.75	2.81***	0.64	1.39**
	**	**	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-121. Squash plant dry weight as affected by location x irrigation method x N-K rate x application time interaction.

Irrigation and N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
		Dry wt (g)		
Overhead				
135-202	28.4	126***[z]	47.1	117**
270-404	132	135NS	66.0	115NS
	**	NS	NS	NS
Drip				
135-202	29.3	141***	17.2	95.0***
270-404	64.9	177***	52.0	98.2*
	**	NS	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

increased with N-K rate, but with all other time x irrigation method combinations, N-K rate did not affect fresh weight.

At Gainesville with fall fertilization with either irrigation method, and at Quincy with fall nutrient application with drip irrigation, plant dry weight increased with an increase in N-K rate (Table 4-121). Rate of N-K did not affect squash plant dry weight at either location with fall + spring fertilization with either irrigation method, or at Quincy with fall application time with overhead irrigation.

Plant dry matter percentage was higher at Gainesville than at Quincy and with drip than with overhead irrigation (Table 4-119). Dry matter percentage was higher with the lower than higher N-K rate but irrigation method and N-K rate interacted in their effect on dry matter percentage (Table 4-122). With overhead irrigation, N-K rate did not affect plant dry matter percentage, but with drip irrigation dry matter percentage increased with an increase in N-K rate. Dry matter percentage was higher with fall than with fall + spring fertilization, but was influenced by interactions between location, irrigation method and time (Table 4-123) and location, N-K rate and time (Table 4-124). At Gainesville with both application times and at Quincy with the fall + spring application time, irrigation method did not affect dry matter percentage; however, at Quincy with fall fertilization time, dry matter percentage was higher with drip than overhead irrigation (Table 4-123). At Gainesville with fall + spring application of nutrients, plant dry matter percentage decreased with an increase in N-K rate; however, with fall fertilization and at

Table 4-122. Squash plant dry matter percentage as affected by irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Dry matter (%)	
	Overhead	Drip
135-202	7.89	9.38*[z]
270-404	7.44	7.62NS
	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-123. Squash plant dry matter percentage as affected by location x irrigation method x application time interaction.

Irrigation	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
		Dry matter (%)		
Overhead	8.96	7.18***[z]	7.37	7.14NS
Drip	9.40	8.61NS	9.00	6.98***
	NS	NS	**	NS

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-124. Squash plant dry matter percentage as affected by location x N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Fall	Fall + spring	Fall	Fall + spring
		Dry matter (%)		
135-202	9.56	9.30NS[z]	8.63	7.05**
270-404	8.81	6.49***	7.75	7.07NS
	NS	*	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Quincy with either application time, values were similar with either N-K rate (Table 4-124).

The number of plants·ha^{-1} was higher at Gainesville than at Quincy, with drip than with overhead irrigation, and with the lower than the higher N-K rate (Table 4-119). However, location, irrigation method and N-K rate interacted in their effect on plant population (Table 4-125). At Gainesville with overhead irrigation and at Quincy with drip, the number of plants·ha^{-1} was similar with either N-K rate but at Gainesville with drip and at Quincy with overhead irrigation, plant population decreased with an increase in N-K rate. Location, N-K rate and time interacted to affect plant population also (Table 4-125). At Gainesville with fall nutrient application, plant population decreased with an increase in N-K rate, but with fall + spring fertilization at Gainesville, and at Quincy with either application time, N-K rate did not affect the number of plants·ha^{-1}.

Gainesville Soil Analyses

At Gainesville, soil pH was not influenced by irrigation method but was higher with the lower than higher N-K rate and with fall than with fall + spring nutrient application (Table 4-126). Values were similar at the center and side of the bed, but application time and bed location interacted in their effect on pH (Table 4-127). At the center of the bed, pH was higher with fall than with fall + spring fertilization, but at the side of the bed, time of application did not affect pH. The effect of increasing depth on soil pH was quadratic (Table 4-126). Soil pH decreased slightly from 0-10 to 10-20 cm depth and decreased significantly from 10-20 to 20-30 cm soil depth.

Table 4-125. Squash plant stand as affected by location x irrigation method x N-K rate and location x N-K rate x application time interactions.

Location and N-K rate ($kg \cdot ha^{-1}$)	Irrigation		Time	
	Overhead	Drip	Fall	Fall + spring
		No. ($1000 \cdot ha^{-1}$)		
Gainesville				
135-202	32.0	35.9*[z]	35.2	32.7NS
270-404	32.6	33.3NS	31.6	34.3*
	NS	*	**	NS
Quincy				
135-202	26.2	26.5NS	25.6	27.1NS
270-404	22.4	26.3**	24.2	24.5NS
	**	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-126. Soil chemical characteristics after squash at Gainesville as affected by irrigation method, N-K rate, application time, bed location and soil depth.

Treatment	pH	EC ($dS \cdot m^{-1}$)	Soil concn (ppm) NO_3-N	NH_4-N	P	K	Ca	Mg
Irrigation (I)								
Overhead	6.57	1.91	12.2	2.96	0.73	22.6	22.6	3.22
Drip	6.57	1.06	1.91	0.19	1.01	8.02	14.0	2.38
Significance[z]	NS	NS	NS	NS	*	*	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)								
135-202	6.63	1.34	5.04	1.18	0.85	10.6	18.2	2.94
270-404	6.52	1.63	9.07	1.96	0.89	20.0	18.4	2.67
Significance	***	NS	NS	NS	NS	***	NS	NS
Time (T)								
Fall	6.61	1.45	7.71	1.52	0.90	13.2	19.5	3.10
Fall + spring	6.53	1.52	6.40	1.63	0.84	17.4	17.1	2.51
Significance	**	NS	NS	NS	NS	NS	NS	NS
IxRxT	NS	NS	*	NS	**	NS	NS	NS
Location (L)								
Center	6.56	1.85	11.2	2.83	1.01	21.3	21.2	3.21
Side	6.58	1.12	2.92	0.32	0.73	9.25	15.4	2.40
Significance	NS	***	**	**	***	***	*	*
IxL	NS	***	**	**	**	***	***	***
TxL	***	NS	NS	NS	NS	NS	*	**
Depth (D) (cm)								
0-10	6.70	2.25	10.5	3.41	0.94	23.9	28.8	4.32
10-20	6.66	1.18	5.28	0.70	0.88	11.9	14.9	2.18
20-30	6.36	1.02	5.40	0.61	0.79	10.1	11.2	1.91
Significance	L*Q**	***	NS	*	NS	***	***	***
IxLxD	NS	*	NS	*	NS	**	*	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

Table 4-127. Soil pH and Ca and Mg concentrations as affected by application time x bed location interaction.

	pH		Ca (ppm)		Mg (ppm)	
Location	Fall	Fall + spring	Fall	Fall + spring	Fall	Fall + spring
Center	6.66	6.47**[z]	25.7	16.8NS	4.05	2.36*
Side	6.57	6.59NS	13.3	17.4**	2.15	2.65NS
	NS	NS	**	NS	**	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Electrical conductivity was not affected by irrigation method, N-K rate or time of application (Table 4-126). Soil EC was higher at the center than the side of the bed and decreased with increased depth of sampling but irrigation method, location and depth interacted to influence EC (Table 4-128). With overhead irrigation, at the center of the bed, the response in EC to increased depth was quadratic but at the side of the bed, values were similar at all depths. With drip irrigation at both bed locations, EC decreased linearly with increased depth.

Soil NO_3-N concentration was not affected by irrigation method, N-K rate or application time (Table 4-126). However, all 3 variables interacted to influence NO_3-N concentration (Table 4-129). With fall fertilization with either irrigation method or with fall + spring application and overhead irrigation, N-K rate did not affect soil NO_3-N concentration but with fall + spring application with drip irrigation, soil NO_3-N concentration increased with an increase in N-K rate. Soil NO_3-N concentration was higher at the center than the side of the bed, but bed location and irrigation method interacted in their effect on NO_3-N concentration (Table 4-130). With overhead irrigation, soil NO_3-N concentration was higher at the center than the side of the bed but with drip irrigation, values were similar at both locations. Soil NO_3-N concentrations were similar at all depths (Table 4-126).

Soil NH_4-N concentration was not influenced by irrigation method, N-K rate or application time. The concentration was higher at the center than the side of the bed and decreased with an increase in

Table 4-128. Soil EC and NH_4-N, K, Ca and Mg concentrations as affected by irrigation method x bed location x soil depth interaction.

Irrigation and depth (cm)	Location		Location		Location	
	Center	Side	Center	Side	Center	Side
	EC ($dS \cdot m^{-1}$)		NH_4-N (ppm)		K (ppm)	
Overhead						
0-10	4.83	1.54**[z]	12.5	0.53*	61.2	17.8 **
10-20	1.78	0.93NS	2.24	0.28NS	23.0	8.77**
20-30	1.51	0.85*	1.87	0.33*	17.7	6.93**
	L***Q*	NS	L***	NS	L***Q*	NS
Drip						
0-10	1.21	1.43NS	0.15	0.47NS	7.64	8.94NS
10-20	0.96	1.06NS	0.13	0.14NS	9.09	6.63NS
20-30	0.80	0.92NS	0.11	0.14NS	9.34	6.45NS
	L**	L***	NS	NS	NS	NS
	Ca (ppm)		Mg (ppm)			
Overhead						
0-10	56.9	19.7*	7.74	2.93**		
10-20	20.5	12.5NS	2.63	1.74NS		
20-30	14.9	11.4NS	2.29	1.98NS		
	L***	NS	L***Q*	NS		
Drip						
0-10	17.1	21.6NS	3.22	3.40NS		
10-20	11.3	15.4*	1.94	2.39NS		
20-30	6.82	11.7***	1.41	1.94NS		
	L***	L***	L***	L**		

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

Table 4-129. Soil NO_3-N and P concentrations as affected by irrigation method x N-K rate x application time interaction.

Time and N-K rate ($kg \cdot ha^{-1}$)	NO_3-N (ppm)		P (ppm)	
	Overhead	Drip	Overhead	Drip
Fall				
135-202	5.56	1.20*[z]	0.85	0.97NS
270-404	22.3	1.77*	0.62	1.16***
	NS	NS	*	NS
Fall + spring				
135-202	12.4	0.96NS	0.63	0.93***
270-404	8.48	3.72NS	0.80	0.98NS
	NS	***	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-130. Soil NO_3-N and P concentrations as affected by irrigation method x bed location interaction.

Location	NO_3-N (ppm)		P (ppm)	
	Overhead	Drip	Overhead	Drip
Center	20.9	1.48***[z]	0.78	1.23***
Side	3.50	2.35NS	0.67	0.79*
	**	NS	NS	***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

depth but irrigation method, location and depth interacted in their effect on soil NH_4-N concentration (Table 4-128). With overhead irrigation at the center of the bed, NH_4-N concentration decreased linearly with an increase in depth but with overhead at the side or with drip irrigation at either bed location, values were similar at all depths.

Soil P concentration was higher with drip than with overhead irrigation but was not influenced by N-K rate or time of application (Table 4-126). However, irrigation method, N-K rate and time interacted to affect soil P concentration (Table 4-129). With fall nutrient application and overhead irrigation, soil P concentration decreased with an increase in N-K rate but with fall fertilization with drip irrigation or fall + spring application with either irrigation method, N-K rate did not affect P concentration. Soil P concentration was higher at the center than the side of the bed but location and irrigation method interacted in their effect on P concentration (Table 4-130). With overhead irrigation, concentrations were similar at both locations but with drip irrigation, soil P concentration was higher at the center than the side of the bed. Soil P concentrations did not differ significantly with increased soil depth (Table 4-126).

At Gainesville, K concentration was higher with overhead than drip irrigation and increased with N-K rate, but was not affected by time of N-K application. Soil K concentration was higher at the center than the side of the bed and decreased with an increase in depth but irrigation method, location and depth interacted to influence K concentration (Table 4-128). With overhead irrigation at

the center of the bed, K concentration decreased with an increase in soil depth, with the greatest concentration difference occurring between the 0-10 cm and 10-20 depths. With overhead irrigation at the side of the bed or with drip irrigation at either location, soil K concentrations were similar at all depths.

Soil Ca concentration was not affected by irrigation method, N-K rate or time (Table 4-126). Soil Ca concentration was higher at the center than the side of the bed but was influenced by an interaction between application time and bed location (Table 4-127). At the center of the bed, Ca concentrations were similar with either application time but at the side, the concentration was higher with fall + spring than with fall nutrient application. The concentration of Ca decreased with an increase in depth but irrigation method, bed location and soil depth interacted to affect soil Ca concentration (Table 4-128). Soil Ca concentration decreased linearly with an increase in depth at both bed locations and with each irrigation method except with overhead irrigation at the side location.

Soil Mg concentration was not influenced by irrigation method, N-K rate or application time (Table 4-126). Soil Mg concentration was higher at the center than at the side of the bed but an interaction between application time and location was significant (Table 4-127). At the center of the bed, soil Mg concentration was higher with fall than with fall + spring nutrient application, but at the side location, values were similar with either application time. With an increase in soil depth, Mg concentration decreased; however, irrigation method, bed location and depth interacted in their effect

on soil Mg concentration (Table 4-128). With overhead irrigation at the bed center, soil Mg decreased with an increase in soil depth with the greater rate of decrease between the 0-10 and 10-20 cm depths. At the side of the bed with overhead irrigation, soil Mg concentrations were similar at all depths. With drip irrigation at both locations, soil Mg concentration decreased linearly with an increase in depth.

Quincy Soil Analyses

Soil pH was not affected by irrigation method or N-K rate, but was higher with the fall than with the fall + spring application time (Table 4-131). Soil pH was higher at the side than at the center of the bed and decreased with an increase in soil depth. Irrigation method, application time and depth interacted in their effect on pH (Table 4-132). With overhead irrigation with fall fertilization, and with drip irrigation with either application time, pH decreased linearly with an increase in soil depth. However, with overhead irrigation with fall + spring N-K application, the pH response to increased depth was quadratic with the greater rate of decrease between the 10-20 and 20-30 cm depths.

At Quincy, soil EC was not influenced by irrigation method or N-K rate, but was higher with fall + spring than with fall nutrient application (Table 4-131). Soil EC was higher at the center than at the side of the bed, but irrigation method, time and location interacted to affect EC (Table 4-133). With fall N-K application with either irrigation method and with fall + spring fertilization with drip irrigation, EC was similar at both bed locations but with fall + spring application and overhead irrigation, EC was significantly

Table 4-131. Soil chemical characteristics after squash at Quincy as affected by irrigation method, N-K rate, application time, bed location and soil depth.

Treatment	pH	EC ($dS \cdot m^{-1}$)	Soil concn (ppm) NO_3-N	NH_4-N	P	K	Ca	Mg
Irrigation (I)								
Gainesville	5.91	1.05	7.96	1.50	0.25	19.8	12.7	4.56
Quincy	6.20	0.56	2.53	0.34	0.31	5.95	5.27	2.13
Significance[z]	NS	NS	NS	NS	NS	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)								
135-202	6.05	0.81	4.19	0.86	0.31	8.51	10.3	3.79
270-404	6.06	0.79	6.24	0.97	0.25	17.0	7.57	2.88
Significance	NS	NS	NS	NS	NS	***	NS	NS
IxR	NS	NS	NS	NS	NS	NS	NS	*
Time (T)								
Fall	6.13	0.61	2.75	0.37	0.31	8.07	6.26	2.50
Fall + spring	5.98	1.00	7.68	1.45	0.25	17.5	11.6	4.17
Significance	***	***	***	***	NS	***	***	**
RxT	NS	NS	NS	NS	NS	NS	*	*
Location (L)								
Center	6.02	0.97	6.72	1.36	0.31	17.4	10.6	3.77
Side	6.09	0.63	3.71	0.46	0.25	8.2	7.24	2.90
Significance	*	***	**	**	NS	***	*	NS
IxTxL	NS	**	*	**	NS	**	**	*
Depth (D) (cm)								
0-10	6.25	1.00	6.92	1.30	0.47	14.7	12.6	4.70
10-20	6.16	0.68	4.22	0.60	0.17	11.0	6.46	2.52
20-30	5.76	0.73	4.51	0.84	0.20	12.7	7.59	2.79
Significance	***	**	NS	NS	***	NS	***	**
IxD	**	*	NS	NS	NS	NS	L*	L*
IxTxD	*	NS	NS	NS	NS	NS	NS	NS
IxRxTxD	NS	NS	NS	NS	L*	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L).

Table 4-132. Soil pH as affected by irrigation method x application time x soil depth interaction.

Depth (cm)	Overhead		Drip	
	Fall	Fall + spring	Fall	Fall + spring
		pH		
0-10	6.27	6.01	6.34	6.37
10-20	6.15	5.92	6.29	6.27
20-30	5.76	5.28	5.95	6.00
	L***	L***Q**	L***	L**

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

Table 4-133. Soil EC and NO_3-N, NH_4-N, K, Ca and Mg concentrations as affected by irrigation method x application time x bed location interaction.

Time, irrigation and location	EC ($dS \cdot m^{-1}$)	Soil concn (ppm)				
		NO_3-N	NH_4-N	K	Ca	Mg
Fall						
Overhead						
Center	0.69	3.31	0.30	12.5	6.80	6.68
Side	0.61	2.79	0.33	9.3	6.99	6.78
	NS[z]	NS	NS	NS	NS	NS
Drip						
Center	0.60	2.60	0.63	5.78	5.27	2.00
Side	0.53	2.32	0.23	4.73	5.96	2.55
	NS	NS	NS	NS	NS	NS
Fall + spring						
Overhead						
Center	2.02	18.5	4.30	43.9	26.0	8.72
Side	0.86	7.24	1.04	13.0	10.9	4.06
	**	**	**	**	*	*
Drip						
Center	0.57	2.49	0.22	7.26	4.43	1.70
Side	0.55	2.70	0.29	6.04	5.39	2.28
	NS	NS	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

higher at the center than at the side of the bed. Soil EC values differed between depths but were influenced by an interaction between irrigation method and soil depth (Table 4-134). With overhead irrigation, EC decreased linearly with an increase in soil depth but with drip irrigation, EC was similar at all depths.

Soil NO_3-N and NH_4-N concentrations were not affected by irrigation method or N-K rate but were higher with fall + spring than with residual fall fertilization (Table 4-131). Soil NO_3-N and NH_4-N concentrations were higher at the bed center than at the side but were influenced by an interaction between irrigation method, application time and bed location (Table 4-133). With fall N-K application with either irrigation method and with fall + spring fertilization with drip irrigation, soil NO_3-N and NH_4-N concentrations were similar at the center and side of the bed but with fall + spring N-K with overhead irrigation, concentrations of NO_3-N and NH_4-N were higher at the center than at the side of the bed. Soil NO_3-N and NH_4-N concentrations were similar at all soil depths (Table 4-131).

Soil P concentration was not affected by main effects of treatments but was influenced by an interaction between irrigation method, N-K rate, time and depth (Table 4-135). With fall applied N-K with the lower rate and overhead irrigation, and with fall + spring fertilization with either N-K rate and drip irrigation, soil P concentration was similar at all soil depths. With fall and fall + spring fertilization with the higher N-K rate and overhead irrigation, and with fall N-K application with either rate and drip irrigation,

Table 4-134. Soil EC and Ca and Mg concentrations as affected by irrigation method x soil depth interaction.

Depth (cm)	EC ($dS \cdot m^{-1}$)		Ca (ppm)		Mg (ppm)	
	Overhead	Drip	Overhead	Drip	Overhead	Drip
0-10	1.41	0.59	19.8	5.70	7.11	2.28
10-20	0.83	0.53	8.1	4.81	3.08	1.96
20-30	0.90	0.58	10.0	5.29	3.46	2.15
	L**[z]	NS	L**Q*	NS	L**Q*	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level. Effects of depth were linear (L) or quadratic (Q).

Table 4-135. Soil P concentration as affected by irrigation method x N-K rate x application time x soil depth interaction.

Irrigation and depth (cm)	Fall		Fall + spring	
	135-202	270-404	135-202	270-404
		P (ppm)		
Overhead				
0-10	0.51	0.64	0.38	0.16
10-20	0.13	0.14	0.11	0.11
20-30	0.43	0.10	0.13	0.10
	NS	L**	L***Q**	L**
Drip				
0-10	0.65	0.43	0.46	0.54
10-20	0.28	0.15	0.23	0.21
20-30	0.10	0.19	0.38	0.19
	L***	L*	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

soil P concentration decreased linearly with an increase in depth. With fall + spring fertilization with the lower N-K rate and overhead irrigation, soil P concentration decreased from the 0-10 to 10-20 cm depth, then increased slightly at the 20-30 cm depth.

Soil K concentrations were similar with either irrigation method (Table 4-131). The concentration of K increased with N-K rate and was higher with fall + spring than with fall-only fertilization. Soil K concentration was higher at the center than at the side location but irrigation method, application time and bed location interacted to affect soil K concentration (Table 4-133). With fall N-K application with either irrigation method and with fall + spring fertilization with drip irrigation, soil K concentrations were similar at both bed locations, but with fall + spring N-K application with overhead irrigation, the K concentration was higher at the center than at the side of the bed. Soil K concentrations were similar at all soil depths (Table 4-131).

Calcium concentration was not affected by irrigation method or N-K rate but was higher with fall + spring than with fall nutrient application (Table 4-131). However, N-K rate and application time interacted in their effect on soil Ca (Table 4-136). With the lower N-K rate, Ca concentration was higher with fall + spring than with fall application but with the higher rate, time of application did not influence soil Ca. Soil Ca was higher at the center than at the side of the bed but was influenced by an interaction between irrigation method, time and location (Table 4-133). With fall fertilization with either irrigation method and with fall + spring N-K application with

Table 4-136. Soil Ca and Mg concentrations as affected by N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Ca (ppm)		Mg (ppm)	
	Fall	Fall + spring	Fall	Fall + spring
135-202	5.97	14.6 **[z]	2.40	5.18**
270-404	6.54	8.60NS	2.60	3.16NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 1% (**) level.

Table 4-137. Soil Mg concentration as affected by irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Mg (ppm)	
	Overhead	Drip
135-202	5.55	2.03**[z]
270-404	3.55	2.24*
	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

drip irrigation, Ca concentrations were similar at both bed locations, but with fall + spring fertilization with overhead irrigation, soil Ca concentration was higher at the center than at the side of the bed. Soil Ca concentration varied with depth but was influenced by an interaction between irrigation method and soil depth (Table 4-134). With overhead irrigation, Ca concentration decreased from the 0-10 to 10-20 cm depth, then increased slightly at the 20-30 cm depth but with drip irrigation, values were similar at all 3 depths.

Soil Mg concentration was not affected by irrigation method or N-K rate but both treatments interacted to influence Mg concentration (Table 4-137). With both N-K rates, soil Mg concentration was higher with overhead than with drip irrigation, with the greater difference associated with the lower N-K rate. Soil Mg concentration was higher with fall + spring than fall fertilization but N-K rate and application time interacted in their effect on Mg concentration (Table 4-136). With the lower N-K rate, Mg concentration was higher with fall + spring than with fall fertilization but with the higher rate, application time did not influence soil Mg concentration. Soil Mg concentrations were similar at the 2 bed locations but were influenced by an interaction between irrigation method, application time and location (Table 4-133). With fall applied N-K with either irrigation method and with fall + spring fertilization with drip irrigation, soil Mg concentrations were similar at both bed locations. With fall + spring fertilization and overhead irrigation, the concentration of Mg was higher at the center than the side of the bed. Soil Mg concentration varied with depth but irrigation method and soil depth

interacted to affect Mg concentration (Table 4-134). With overhead irrigation, soil Mg concentration decreased from 0-10 to 10-20 cm, then increased slightly from 10-20 to 20-30 cm. With drip irrigation, soil Mg concentration was not affected by depth.

1984 Broccoli Field Experiment

Yield

Early yield of broccoli was significantly higher at Gainesville than at Quincy (Table 4-138). Early broccoli yield was not influenced by irrigation method, but increased with an increase in N-K rate, and was higher with the fall + fall than with the residual fall + spring N-K application time. Crop sequence did not affect early yield, but location, irrigation method, N-K rate, time and sequence interacted in their effect on early yield of broccoli (Table 4-139). At Gainesville, with fall + fall fertilization and either crop sequence with overhead or drip irrigation, early broccoli yield was not affected by N-K rate. With fall + spring N-K application, and either sequence with overhead irrigation, early yield was higher with the higher than lower N-K rate but with drip irrigation, yields were similar with each rate. At Quincy with either N-K application time with the broccoli-tomato-broccoli (Br-Tm-Br) sequence with either irrigation method and with the broccoli-squash-broccoli (Br-Sq-Br) sequence with overhead irrigation, yields were similar with both N-K rates. However, with both application times and drip irrigation, early broccoli yield following squash increased with an increase in N-K rate.

Table 4-138. Marketable yield of broccoli as affected by location, irrigation method, N-K rate, time and crop sequence, 1984.

Treatment	Yield ($t \cdot ha^{-1}$) Early	Late	Total	No. ($1000 \cdot ha^{-1}$)	Head wt (g)
Location (L)					
Gainesville	5.0	1.6	6.6	25.1	230
Quincy	2.9	5.1	8.0	26.3	295
Significance[z]	*	***	NS	NS	***
Irrigation (I)					
Overhead	4.5	3.1	7.6	28.2	263
Drip	3.6	3.2	6.8	23.1	253
Significance	NS	NS	NS	**	NS
N-K rate (R) ($kg \cdot ha^{-1}$)					
135-202	3.5	3.1	6.6	24.1	245
270-404	4.6	3.1	7.8	27.2	271
Significance	***	NS	***	***	***
LxIxR	***	NS	***	*	***
Time (T)					
Fall + fall	6.7	3.8	10.5	33.4	315
Fall + spring	1.5	2.4	3.9	17.8	201
Significance	***	***	***	***	***
LxT	***	***	NS	NS	***
LxIxT	***	NS	***	***	*
LxRxT	NS	NS	NS	*	NS
Sequence (S)					
Br-Tm-Br	3.9	3.0	6.9	25.0	255
Br-Sq-Br	4.2	3.2	7.5	26.3	261
Significance	NS	NS	*	NS	NS
IxTxS	NS	**	**	**	NS
LxIxRxTxS	**	NS	*	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-139. Early yield of broccoli as affected by location x irrigation method x N-K rate x application time x crop sequence interaction.

Location, time, and N-K rate ($kg \cdot ha^{-1}$)	Br-Tm-Br		Br-Sq-Br	
	Overhead	Drip	Overhead	Drip
	Yield ($t \cdot ha^{-1}$)			
Gainesville				
Fall + fall				
135-202	5.4	8.8NS[z]	7.7	7.3NS
270-404	9.1	8.4NS	9.3	9.2NS
	NS	NS	NS	NS
Fall + spring				
135-202	0.7	0.0NS	2.3	0.0*
270-404	4.4	0.9***	5.5	0.4***
	***	NS	*	NS
Quincy				
Fall + fall				
135-202	8.0	2.9NS	4.7	3.4NS
270-404	3.4	5.5NS	5.3	4.8NS
	NS	NS	NS	*
Fall + spring				
135-202	1.3	0.5NS	1.4	0.7NS
270-404	0.5	1.0NS	0.7	2.5**
	NS	NS	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Late broccoli yield was 5.1 $t \cdot ha^{-1}$ at Quincy and 1.6 $t \cdot ha^{-1}$ at Gainesville, but was not affected by irrigation method or N-K rate (Table 4-138). Yield was higher with fall + fall than with fall + spring nutrient application but location and time interacted to affect late broccoli yield (Table 4-140). At Gainesville, yields were similar with either application time but at Quincy, late broccoli yield was higher with fall + fall than with fall + spring fertilization. Late yield was not affected by sequence, but irrigation method, time and sequence combined to influence broccoli yield (Table 4-141). With the Br-Tm-Br sequence and either application time, irrigation method did not affect late broccoli yield. With the Br-Sq-Br sequence and fall + fall nutrient application, late broccoli yield was higher with drip than with overhead irrigation, but with fall + spring fertilization, late yield was higher with overhead than with drip.

Total yield of broccoli was not affected by location or irrigation method but increased with N-K rate and was higher with fall + fall than with residual fall + spring N-K application (Table 4-138). Total yield was higher following squash than tomato, but sequence, location, irrigation method, N-K rate and time interacted in their effect on total broccoli yield (Table 4-142). With the Br-Tm-Br sequence and overhead irrigation at Gainesville with both application times, total yield increased with N-K rate. Nutrient application rate did not affect broccoli yield with any other combination of treatments with the Br-Tm-Br sequence. Total yield of broccoli following squash

Table 4-140. Late yield of broccoli as affected by location x time interaction.

Time	Late yield ($t \cdot ha^{-1}$)	
	Gainesville	Quincy
Fall + fall	1.8	6.5
Fall + spring	1.5	3.7
	NS[z]	***

[z] Effects were not significant (NS) or significant at the 0.1% (***) level.

Table 4-141. Late yield and number of heads of broccoli as affected by irrigation method x time x sequence interactions.

Sequence and irrigation	Late yield ($t \cdot ha^{-1}$)		No. ($1000 \cdot ha^{-1}$)	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
Br-Tm-Br				
Overhead	3.2	2.4NS[z]	33.6	19.4**
Drip	4.0	2.3*	32.3	14.5***
	NS	NS	NS	NS
Br-Sq-Br				
Overhead	3.1	3.4NS	34.1	25.7NS
Drip	4.9	1.5***	33.7	11.8***
	*	***	NS	***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

at Gainesville increased with an increase in rate of fall + spring N-K application and either irrigation method. With fall + fall fertilization at Gainesville with either irrigation method, yields were similar with both N-K rates. At Quincy with either application time and drip irrigation, total broccoli yield was higher with the higher than lower N-K rate but with overhead irrigation and either time, N-K rate did not influence total yield.

The number of broccoli heads produced was similar at both locations but was higher with overhead than with drip irrigation (Table 4-138). The number of heads increased with N-K rate and was higher with fall + fall than fall + spring fertilization, but was influenced by an interaction between location, irrigation method and time (Table 4-143). At Gainesville with the residual fall + spring application, broccoli head number was significantly lower with drip than with overhead irrigation. With fall + fall fertilization, and at Quincy with either application time, head number was not affected by irrigation method. Location, N-K rate and time also interacted to influence the number of broccoli heads$\cdot ha^{-1}$ (Table 4-144). At Gainesville, with residual fall + spring N-K application, the number of heads increased with N-K rate but with fall + fall fertilization and at Quincy with either application time, N-K rate did not influence the number of broccoli heads produced. Crop sequence did not affect broccoli head number, but irrigation method, time and sequence interacted (Table 4-141). With either time of N-K application with the Br-Tm-Br sequence and with fall + fall nutrient application with

Table 4-142. Total yield of broccoli as affected by location x irrigation method x N-K rate x application time x crop sequence interaction.

Location, time, and N-K rate ($kg \cdot ha^{-1}$)	Br-Tm-Br		Br-Sq-Br	
	Overhead	Drip	Overhead	Drip
	Yield ($t \cdot ha^{-1}$)			
Gainesville				
Fall + fall				
135-202	7.3	9.9NS[z]	9.6	9.8NS
270-404	10.7	10.2NS	10.5	11.8NS
	*	NS	NS	NS
Fall + spring				
135-202	2.4	0.8NS	4.8	0.4**
270-404	6.3	2.1**	7.6	1.5***
	*	NS	*	*
Quincy				
Fall + fall				
135-202	12.9	11.2NS	10.5	11.3NS
270-404	9.0	12.3NS	10.3	12.9*
	NS	NS	NS	*
Fall + spring				
135-202	4.8	3.9NS	7.1	2.4**
270-404	3.6	5.6NS	4.9	5.8NS
	NS	NS	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-143. Number and average weight of broccoli heads as affected by location x irrigation method x application time interactions.

Location and irrigation	No. ($1000 \cdot ha^{-1}$)		Wt (g)	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
Gainesville				
Overhead	33.3	26.3**[z]	286	200***
Drip	31.4	9.7***	332	125***
	NS	***	**	***
Quincy				
Overhead	20.8	10.5***	308	292NS
Drip	21.2	10.7***	337	249***
	NS	NS	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

the Br-Sq-Br sequence, irrigation method did not affect broccoli head number. However, with fall + spring fertilization the number of broccoli heads produced after squash was lower with drip than with overhead irrigation.

The average weight of broccoli heads was higher at Quincy than at Gainesville but was not affected by irrigation method (Table 4-138). Head weight increased with N-K rate but was influenced by an interaction between location, irrigation method and N-K rate (Table 4-145). At Gainesville with overhead irrigation, average head weight increased with an increase in N-K rate but with drip irrigation at Gainesville and at Quincy with both irrigation methods, head weight was not affected by N-K rate. Broccoli head weight was higher with fall + fall than with fall + spring fertilization but location, irrigation method and time interacted in their effect on average head weight (Table 4-143). With fall + fall application at Gainesville, head weight was higher with drip than overhead irrigation but with residual fall + spring fertilization at both locations head weight was higher with overhead than with drip irrigation. At Quincy with fall + fall N-K application, irrigation method did not influence broccoli head weight. Broccoli head average weights were similar with either crop sequence (Table 4-138).

Tissue Analyses

Total N concentrations in leaf, head and plant tissue were higher at Quincy than at Gainesville and with the higher N-K rate, but were not affected by irrigation method (Table 4-146). Plant N concentration was influenced by an interaction between location,

Table 4-144. Number of broccoli heads as affected by location x N-K rate x application time interactions.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
		No. ($1000 \cdot ha^{-1}$)		
135-202	31.7	13.7***[z]	34.5	17.3***
270-404	32.9	22.2***	35.5	18.0***
	NS	*	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-145. Average weight of broccoli heads as affected by location x irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Overhead	Drip	Overhead	Drip
		Wt (g)		
135-202	207	210NS[z]	317	272NS
270-404	267	237NS	278	314NS
	**	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 1% (**) level.

Table 4-146. Nitrogen concentration of broccoli as affected by location, irrigation method, N-K rate, application time and crop sequence, 1984.

Treatment	N concn (%)		
	Leaf	Head	Plant
Location (L)			
Gainesville	3.61	3.41	2.06
Quincy	4.02	4.13	3.15
Significance[z]	**	***	***
Irrigation (I)			
Overhead	3.75	3.87	2.64
Drip	3.83	3.56	2.42
Significance	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)			
135-202	3.66	3.59	2.26
270-404	3.82	3.85	2.80
Significance	*	*	***
LxIxR	NS	NS	*
Time (T)			
Fall + fall	4.55	4.44	2.88
Fall + spring	3.03	2.99	2.19
Significance	***	***	***
LxT	NS	***	*
IxT	***	***	***
LxRxT	**	NS	*
Sequence (S)			
Br-Tm-Br	3.67	3.65	2.54
Br-Sq-Br	3.91	3.78	2.52
Significance	NS	NS	NS
LxIxS	NS	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

irrigation method and N-K rate (Table 4-147). At Gainesville with overhead irrigation, plant N concentration increased with an increase in N-K rate, but with drip irrigation or at Quincy with either irrigation method, N-K did not affect significantly plant N concentration. All tissue N concentrations were higher with fall + fall than with residual fall + spring N-K application, but several treatments interacted with time (Table 4-146). With fall + fall nutrient application, leaf N concentrations were higher with drip than with overhead irrigation but with fall + spring fertilization, leaf N concentrations were lower with drip than overhead irrigation (Table 4-148). At Gainesville with either nutrient application time and at Quincy with fall + fall N-K application, leaf N concentrations were not affected by N-K rate (Table 4-149). However, at Quincy with fall + spring fertilization, leaf N concentration increased with N-K rate. Broccoli head N concentration was influenced by location x time (Table 4-150) and irrigation x time (Table 4-148) interactions. At both locations, head N concentration was higher with fall + fall than fall + spring N-K application; however, the difference in N concentration was greater at Gainesville (Table 4-150). With fall + fall fertilization, head N concentrations were similar with each irrigation method, but with fall + spring application time, broccoli head N concentration was higher with overhead than with drip irrigation (Table 4-148). Plant N concentration was affected by irrigation method x time (Table 4-148) and location x N-K rate x time (Table 4-149) interactions. With fall + fall fertilization, plant N

Table 4-147. Broccoli plant N concentration as affected by location x irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Overhead	Drip	Overhead	Drip
		N concn (%)		
135-202	1.56	1.88NS[z]	3.26	2.71*
270-404	2.62	2.19NS	3.50	3.15NS
	***	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-148. Broccoli leaf, head and plant N concentrations as affected by irrigation method x time interaction.

Irrigation	Leaf		Head		Plant	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring	Fall + fall	Fall + spring
			N concn (%)			
Overhead	4.28	3.22***[z]	4.40	3.34***	2.82	2.47NS
Drip	4.82	2.84***	4.48	2.64***	2.93	1.90***
	*	*	NS	**	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-149. Broccoli leaf and plant N concentrations as affected by location x N-K rate x time interaction.

Location and N-K rate ($kg \cdot ha^{-1}$)	Leaf		Plant	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
	N concn (%)			
Gainesville				
135-202	4.35	2.75***[z]	2.03	1.41**
270-404	4.25	3.12***	2.97	1.85***
	NS	NS	***	**
Quincy				
135-202	4.68	2.95***	3.30	2.66**
270-404	5.09	3.37***	3.45	3.20NS
	NS	*	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-150. Broccoli head N concentration as affected by location x time interaction.

Time	N concn (%)	
	Gainesville	Quincy
Fall + fall	4.36	4.55
Fall + spring	2.46	3.71
	***[z]	***

[z] Effects were not significant (NS) or significant at the 0.1% (***) level.

concentration was similar with overhead or drip irrigation but with fall + spring N-K application, plant N concentration was higher with overhead than with drip irrigation (Table 4-148). At Gainesville with either application time, plant N concentration increased with N-K rate but at Quincy, with either time, plant N concentration was not influenced by N-K rate (Table 4-149). Crop sequence did not affect N concentration of any tissue but location, irrigation method and sequence interacted to influence broccoli plant N concentration (Table 4-151). At Gainesville with either sequence and at Quincy with the Br-Tm-Br sequence, irrigation method did not affect plant N concentration. However, at Quincy with the Br-Sq-Br sequence, plant N concentration was higher with overhead than with drip irrigation.

Leaf, head and plant P concentrations were higher at Gainesville than Quincy (Table 4-152). Broccoli leaf P concentration was higher with drip than with overhead irrigation but head and plant concentrations were similar with either irrigation method. Rate of N-K did not affect leaf P concentration. Head and plant P concentrations increased with N-K rate, but location interacted with N-K rate to affect head P concentration (Table 4-153). At Gainesville, head P concentration was higher with the higher than the lower N-K rate but at Quincy, concentrations were similar with either rate. Leaf P concentration was not affected by time of nutrient application but was influenced by an interaction between location, irrigation method and time (Table 4-154). At Gainesville with either application time and at Quincy with fall + spring fertilization, leaf P concentration was higher with drip than with overhead irrigation.

Table 4-151. Broccoli plant N concentration as affected by location x irrigation method x sequence interaction.

Sequence	Gainesville		Quincy	
	Overhead	Drip	Overhead	Drip
	N concn (%)			
Br-Tm-Br	2.22	1.85NS[z]	3.39	3.04NS
Br-Sq-Br	1.96	2.23NS	3.37	2.81**
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 1% (**) level.

Table 4-152. Phosphorus concentration of broccoli as affected by location, irrigation method, N-K rate, application time and crop sequence, 1984.

Treatment	P concn (%)		
	Leaf	Head	Plant
Location (L)			
Gainesville	0.82	0.72	0.54
Quincy	0.59	0.62	0.46
Significance[z]	***	**	*
Irrigation (I)			
Overhead	0.67	0.67	0.49
Drip	0.78	0.68	0.52
Significance	***	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)			
135-202	0.73	0.66	0.49
270-404	0.71	0.69	0.52
Significance	NS	*	*
LxR	NS	***	**
Time (T)			
Fall + fall	0.74	0.73	0.54
Fall + spring	0.71	0.62	0.47
Significance	NS	***	***
IxT	NS	***	**
LxIxT	***	***	NS
Sequence (S)			
Br-Tm-Br	0.70	0.66	0.50
Br-Sq-Br	0.74	0.69	0.51
Significance	**	NS	NS
LxRxTxS	NS	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-153. Broccoli head P concentration as affected by location x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	P concn (%)	
	Gainesville	Quincy
135-202	0.68	0.63
270-404	0.75	0.60
	*[z]	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-154. Broccoli leaf and head P concentrations as affected by location x irrigation method x application time interaction.

Location and irrigation	Leaf		Head	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
	P concn (%)			
Gainesville				
Overhead	0.73	0.77NS[z]	0.79	0.65***
Drip	0.96	0.84**	0.89	0.56***
	***	*	**	***
Quincy				
Overhead	0.60	0.53**	0.60	0.63NS
Drip	0.58	0.64NS	0.61	0.63NS
	NS	***	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

However, at Quincy with fall + fall N-K application, concentrations were similar with either irrigation method. Head P concentration was higher with fall + fall than fall + spring fertilization, but was influenced by a location x irrigation method x time interaction (Table 4-154). At Gainesville with fall + fall N-K application, head P concentration was higher with drip than with overhead irrigation but with fall + spring application time, the opposite response occurred. At Quincy with either time of application, head P concentrations were similar with either irrigation method. Plant P concentration was higher with fall + fall than fall + spring nutrient application but irrigation method and time interacted to influence P concentration (Table 4-155). With fall + fall N-K application, plant P concentration was higher with drip than with overhead irrigation but with residual fall + spring fertilization, irrigation method did not affect plant P concentration. Broccoli leaf P concentration was higher following squash than tomato, but head and plant P concentrations were not influenced by sequence (Table 4-152). However, plant P concentration was affected by an interaction between location, N-K rate, time and sequence (Table 4-156). At Gainesville with the Br-Tm-Br sequence with fall + spring fertilization and with the Br-Sq-Br sequence with fall + fall application, plant P concentration increased with N-K rate. Rate of N-K did not affect plant P concentration with any other location x time x sequence treatment combination.

Broccoli leaf and head K concentrations were similar at Gainesville and Quincy, but plant K concentration was higher at the

Table 4-155. Broccoli plant P concentration as affected by irrigation method x application time interaction.

Irrigation	P concn (%)	
	Fall + fall	Fall + spring
Overhead	0.51	0.47NS[z]
Drip	0.58	0.46***
	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-156. Broccoli plant P concentration as affected by location x N-K rate x application time x crop sequence interaction.

Location and N-K rate ($kg \cdot ha^{-1}$)	Br-Tm-Br		Br-Sq-Br	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
	P concn (%)			
Gainesville				
135-202	0.55	0.44**[z]	0.55	0.50NS
270-404	0.62	0.50*	0.67	0.51**
	NS	*	*	NS
Quincy				
135-202	0.46	0.47NS	0.50	0.43*
270-404	0.48	0.42NS	0.42	0.47NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Gainesville location (Table 4-157). Leaf and plant K concentrations were higher with overhead than with drip irrigation, but head K concentration was not affected by irrigation method. Potassium concentration of all tissues increased with an increase in N-K rate but location, irrigation method and N-K rate interacted to influence leaf K concentration (Table 4-158). At Gainesville with either irrigation method and at Quincy with drip irrigation, leaf K concentrations increased with N-K rate. However, at Quincy with overhead irrigation, N-K rate did not affect broccoli leaf K concentration. Location and N-K rate interacted to influence broccoli head K concentration (Table 4-159). At Gainesville, head K concentration was higher with the higher than the lower N-K rate, but at Quincy, N-K rate did not affect head K concentration. In all tissues, K concentration was higher with fall + fall than with fall + spring fertilization but location and time interacted to affect leaf and head K concentrations (Table 4-160). At Gainesville, leaf K concentrations were higher with fall + fall than with fall + spring nutrient application but at Quincy, time of application did not affect leaf K concentration. At both locations, broccoli head K concentration was higher with fall + fall than fall + spring fertilization but the rate of increase in K concentration was greater at Gainesville than at Quincy. Irrigation method also interacted with application time to influence head and plant K concentrations (Table 4-161). With fall + fall N-K application, head K concentration was higher with drip than with overhead irrigation, but with fall + spring

Table 4-157. Potassium concentration of broccoli as affected by location, irrigation method, N-K rate, application time and crop sequence, 1984.

Treatment	K concn (%)		
	Leaf	Head	Plant
Location (L)			
Gainesville	3.78	3.89	4.54
Quincy	4.05	3.89	3.88
Significance[z]	NS	NS	*
Irrigation (I)			
Overhead	4.22	3.87	4.40
Drip	3.58	3.91	4.11
Significance	**	NS	*
N-K rate (R) ($kg \cdot ha^{-1}$)			
135-202	3.51	3.71	3.89
270-404	4.28	4.07	4.63
Significance	***	***	***
LxR	NS	*	***
LxIxR	**	NS	NS
Time (T)			
Fall + fall	4.27	4.24	4.71
Fall + spring	3.52	3.54	3.80
Significance	***	***	***
LxT	***	***	NS
IxT	NS	***	***
Sequence (S)			
Br-Tm-Br	3.85	3.91	4.25
Br-Sq-Br	3.94	3.88	4.26
Significance	NS	NS	NS
LxIxRxS	NS	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-158. Broccoli leaf K concentration as affected by location x irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Overhead	Drip	Overhead	Drip
	K concn (%)			
135-202	3.73	3.01*[z]	3.96	3.45*
270-404	4.84	3.54***	4.30	4.50NS
	***	*	NS	***

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-159. Broccoli head K concentration as affected by location x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	K concn (%)	
	Gainesville	Quincy
135-202	3.63	3.80
270-404	4.14	3.98
	***[z]	NS

[z] Effects were not significant (NS) or significant at the 0.1% (***) level.

Table 4-160. Broccoli leaf and head K concentrations as affected by location x application time interaction.

Time	Leaf		Head	
	Gainesville	Quincy	Gainesville	Quincy
	K concn (%)			
Fall + fall	4.32	4.21	4.39	4.03
Fall + spring	3.24	3.90	3.39	3.75
	***[z]	NS	***	**

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-161. Broccoli head and plant K concentrations as affected by irrigation method x application time interaction.

Irrigation	Head		Plant	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
	K concn (%)			
Overhead	4.03	3.71**[z]	4.61	4.19NS
Drip	4.44	3.38***	4.81	3.42***
	**	***	NS	***

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

fertilization, the opposite effect occurred. Broccoli plant K concentration was not affected by irrigation method with fall + fall application time. However, with the residual fall + spring application, plant K concentration was lower with drip than with overhead irrigation. Leaf, head and plant K concentrations were not influenced by crop sequence but location, irrigation method, N-K rate and sequence interacted to affect plant K concentration (Table 4-162). At Gainesville with the Br-Tm-Br sequence with overhead irrigation and with the Br-Sq-Br sequence with either irrigation method, broccoli plant K concentrations increased with an increase in N-K rate. However, N-K rate did not affect plant K concentrations at Gainesville with the Br-Tm-Br sequence and drip irrigation, or at Quincy with any treatment combination.

In all tissues, the Ca concentrations were higher at Gainesville than at Quincy (Table 4-163). Irrigation method did not affect tissue Ca concentrations but location and irrigation method interacted to influence head Ca concentration (Table 4-164). At Gainesville, broccoli head Ca concentration was higher with drip than with overhead irrigation but at Quincy, head Ca concentration was higher with overhead than drip. Rate of N-K did not influence Ca concentration of broccoli tissues (Table 4-163) but location interacted with N-K rate to affect leaf Ca concentration (Table 4-165). At Gainesville, N-K rate did not affect leaf Ca concentration but at Quincy, concentration of Ca decreased with an increase in N-K rate. Leaf Ca concentration was higher with fall + fall than fall + spring fertilization but was influenced by a location x irrigation method x time interaction

Table 4-162. Broccoli plant K concentration as affected by location x irrigation method x N-K rate x crop sequence interaction.

Location and N-K rate ($kg \cdot ha^{-1}$)	Br-Tm-Br		Br-Sq-Br	
	Overhead	Drip	Overhead	Drip
		K concn (%)		
Gainesville				
135-202	4.07	3.99NS[z]	4.16	3.79NS
270-404	5.33	4.43*	5.38	5.15NS
	***	NS	***	**
Quincy				
135-202	4.08	3.52NS	3.59	3.73NS
270-404	4.14	4.18NS	4.02	3.80NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-163. Calcium concentration of broccoli as affected by location, irrigation method, N-K rate, application time and crop sequence, 1984.

Treatment	Ca concn (%)		
	Leaf	Head	Plant
Location (L)			
Gainesville	3.83	0.77	2.87
Quincy	3.31	0.69	2.46
Significance[z]	*	*	**
Irrigation (I)			
Overhead	3.49	0.71	2.70
Drip	3.72	0.77	2.70
Significance	NS	NS	NS
LxI	NS	*	*
N-K rate (R) ($kg \cdot ha^{-1}$)			
135-202	3.62	0.74	2.63
270-404	3.59	0.73	2.78
Significance	NS	NS	NS
LxR	***	NS	*
Time (T)			
Fall + fall	3.83	0.72	2.81
Fall + spring	3.38	0.76	2.60
Significance	***	*	**
LxIxT	**	NS	NS
LxIxRxT	NS	NS	**
Sequence (S)			
Br-Tm-Br	3.63	0.76	2.76
Br-Sq-Br	3.58	0.72	2.65
Significance	NS	NS	NS
IxS	**	NS	*
IxTxS	*	NS	NS
LxRxTxS	NS	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-164. Broccoli head Ca concentration as affected by location x irrigation method interaction.

Irrigation	Ca concn (%)	
	Gainesville	Quincy
Overhead	0.70	0.72
Drip	0.85	0.66
	***[z]	*

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-165. Broccoli leaf Ca concentration as affected by location x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Ca concn (%)	
	Gainesville	Quincy
135-202	3.73	3.48
270-404	3.93	3.14
	NS[z]	**

[z] Effects were not significant (NS) or significant at the 1% (**) level.

(Table 4-166). At Gainesville with fall + fall application, leaf Ca concentration was higher with drip than with overhead irrigation but with fall + spring application or at Quincy with either application time, concentrations were similar with overhead or drip irrigation. Head Ca concentration was higher with residual fall + spring than with fall + fall nutrient application but plant Ca concentration was higher with fall + fall fertilization (Table 4-163). However, location, irrigation method, N-K rate and time interacted in their effect on plant Ca concentration (Table 4-167). At Gainesville with overhead irrigation with fall + spring nutrient application, plant Ca concentration increased with N-K rate but with any other location x irrigation method x time treatment combination, N-K rate did not affect plant Ca concentrations. Crop sequence did not affect broccoli Ca concentrations but irrigation method, time and sequence interacted to influence leaf Ca concentration (Table 4-168). With the Br-Sq-Br sequence with fall + fall N-K application, broccoli leaf Ca concentration was higher with drip than with overhead irrigation. However, irrigation method did not affect leaf Ca concentration with any other time x sequence combination. Broccoli plant Ca concentration was influenced by an irrigation method x sequence interaction (Table 4-169). With overhead irrigation plant Ca concentration was higher following tomato than following squash but with drip irrigation, concentrations were similar with either crop sequence. Location, N-K rate, application time and sequence interacted to affect plant Ca concentration (Table 4-170). At Gainesville with each N-K rate and each crop sequence, plant Ca

Table 4-166. Broccoli leaf Ca concentration as affected by location x irrigation method x application time interaction.

Irrigation	Gainesville		Quincy	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
	Ca concn (%)			
Overhead	3.63	3.54NS[z]	3.48	3.28NS
Drip	4.61	3.54***	3.43	3.05*
	***	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-167. Broccoli plant Ca concentration as affected by location x irrigation method x N-K rate x time interaction.

Location and N-K rate ($kg \cdot ha^{-1}$)	Overhead		Drip	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
		Ca concn (%)		
Gainesville				
135-202	2.88	2.36**[z]	3.14	2.56**
270-404	3.08	2.77*	3.56	2.65**
	NS	**	NS	NS
Quincy				
135-202	2.38	3.00*	2.39	2.22NS
270-404	2.51	2.57NS	2.04	2.71*
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-168. Broccoli leaf Ca concentration as affected by irrigation method x time x sequence interaction.

Irrigation	Br-Tm-Br		Br-Sq-Br	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
	Ca concn (%)			
Overhead	3.76	3.49NS[z]	3.36	3.36NS
Drip	3.93	3.36*	4.28	3.30***
	NS	NS	***	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-169. Broccoli plant Ca concentration as affected by irrigation method x sequence interaction.

Irrigation	Ca concn (%)	
	Br-Tm-Br	Br-Sq-Br
Overhead	2.84	2.56*[z]
Drip	2.68	2.73NS
	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-170. Broccoli plant Ca concentration as affected by location x N-K rate x application time x crop sequence interaction.

Location and N-K rate ($kg \cdot ha^{-1}$)	Br-Tm-Br		Br-Sq-Br	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
	Ca concn (%)			
Gainesville				
135-202	3.08	2.44**[z]	2.94	2.48*
270-404	3.39	2.73*	3.26	2.69*
	NS	NS	NS	NS
Quincy				
135-202	2.29	2.83NS	2.48	2.39NS
270-404	2.33	2.81NS	2.22	2.47NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

concentrations were higher with fall + fall than with fall + spring fertilization but at Quincy with either N-K rate with each sequence, application time did not affect plant Ca concentrations.

Broccoli leaf and plant Mg concentrations were higher at Quincy than at Gainesville but head concentration was not affected by location (Table 4-171). Leaf and head Mg concentrations were similar with either irrigation method but plant Mg concentration was higher with overhead than with drip irrigation. Leaf Mg decreased with an increase in N-K rate but location and N-K rate interacted in their effect on Mg concentration (Table 4-172). At Gainesville, leaf Mg concentrations were similar with either N-K rate but at Quincy, Mg concentration was lower with the higher N-K rate. Broccoli head and plant Mg concentrations were not influenced by N-K rate, but location and rate interacted to affect head Mg concentration (Table 4-172). Head Mg concentration was not influenced by rate at either location but was higher at the Quincy than Gainesville location with either rate of N-K application. Leaf Mg concentration was not affected by application time but head and plant Mg concentrations were higher with fall + fall than with fall + spring N-K application (Table 4-171). However, location, irrigation method and time interacted to influence head Mg concentration (Table 4-173). At Gainesville with fall + fall fertilization, head Mg concentration was higher with drip than with overhead irrigation but with fall + spring fertilization, or at Quincy with fall + fall nutrient application, broccoli head Mg concentration was higher with overhead than with drip irrigation. At Quincy with fall + spring N-K application, irrigation method did not influence

Table 4-171. Magnesium concentration of broccoli as affected by location, irrigation method, N-K rate, application time and crop sequence, 1984.

Treatment	Mg concn (%)		
	Leaf	Head	Plant
Location (L)			
Gainesville	0.54	0.24	0.39
Quincy	0.82	0.28	0.48
Significance[z]	**	NS	*
Irrigation (I)			
Overhead	0.65	0.26	0.44
Drip	0.67	0.25	0.42
Significance	NS	NS	*
N-K rate (R) ($kg \cdot ha^{-1}$)			
135-202	0.70	0.26	0.42
270-404	0.62	0.25	0.44
Significance	***	NS	NS
LxR	**	*	*
Time (T)			
Fall + fall	0.67	0.27	0.44
Fall + spring	0.65	0.24	0.42
Significance	NS	***	*
LxIxT	NS	*	NS
LxIxRxT	NS	NS	**
Sequence (S)			
Br-Tm-Br	0.66	0.26	0.44
Br-Sq-Br	0.66	0.25	0.42
Significance	NS	NS	NS
LxTxS	*	NS	*
LxIxTxS	*	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-172. Broccoli leaf and head Mg concentrations as affected by location x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Leaf		Head	
	Gainesville	Quincy	Gainesville	Quincy
	Mg concn (%)			
135-202	0.56	0.89	0.23	0.29***[z]
270-404	0.52	0.75	0.24	0.27**
	NS	***	NS	NS

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-173. Broccoli head Mg concentration as affected by location x irrigation method x application time interaction.

Irrigation	Gainesville		Quincy	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
		Mg concn (%)		
Overhead	0.25	0.22***[z]	0.30	0.29NS
Drip	0.28	0.20***	0.26	0.26NS
	*	**	***	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

broccoli head Mg concentration. Location, irrigation method, N-K rate and time interacted in their effect on plant Mg concentration (Table 4-174). At Gainesville with overhead irrigation with residual fall + spring application, plant Mg concentration increased with N-K rate. Rate of N-K application did not affect plant Mg concentration with any other location x irrigation method x time combination of treatments. Crop sequence did not influence Mg concentration of any tissue but location, irrigation method, time and sequence interacted to affect leaf Mg concentration (Table 4-175). At Gainesville with the Br-Tm-Br sequence with either time of N-K application, leaf Mg concentrations were similar with either irrigation method, but with the Br-Sq-Br sequence with either time, leaf Mg concentration was higher with drip than with overhead irrigation. At Quincy with the Br-Tm-Br sequence with fall + fall fertilization, leaf Mg concentration was higher with overhead than with drip irrigation but with fall + spring nutrient application or following squash with either application time, irrigation method did not affect broccoli leaf Mg concentration. Location, time and sequence interacted in their effect on broccoli plant Mg concentration (Table 4-176). At Gainesville, with each sequence, plant Mg concentration was higher with fall + fall than with fall + spring applied N-K but at Quincy with either sequence, time of application did not influence plant Mg concentration.

Broccoli head dry matter percentage was higher at Quincy than at Gainesville, and with drip than with overhead irrigation (Table 4-177). Dry matter percentage decreased with an increase in N-K rate,

Table 4-174. Broccoli plant Mg concentration as affected by location x irrigation method x N-K rate x application time interaction.

Location and N-K rate ($kg \cdot ha^{-1}$)	Overhead		Quincy	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
		Mg concn (%)		
Gainesville				
135-202	0.39	0.34*[z]	0.41	0.36*
270-404	0.42	0.38*	0.46	0.38**
	NS	**	NS	NS
Quincy				
135-202	0.51	0.58NS	0.47	0.40NS
270-404	0.52	0.51NS	0.39	0.48NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-175. Broccoli leaf Mg concentration as affected by location x irrigation method x application time x crop sequence interaction.

Location and irrigation	Br-Tm-Br		Br-Sq-Br	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
		Mg concn (%)		
Gainesville				
Overhead	0.54	0.50NS[z]	0.48	0.46NS
Drip	0.59	0.54NS	0.64	0.58NS
	NS	NS	**	**
Quincy				
Overhead	0.90	0.82NS	0.83	0.87NS
Drip	0.71	0.84NS	0.83	0.79NS
	*	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-176. Broccoli plant Mg concentration as affected by location x application time x crop sequence interaction.

Sequence	Gainesville		Quincy	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
	Mg concn (%)			
Br-Tm-Br	0.43	0.37***[z]	0.47	0.53NS
Br-Sq-Br	0.41	0.36**	0.48	0.45NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-177. Broccoli head dry matter percentage and plant fresh and dry weights, dry matter percentage and number as affected by location, irrigation method, N-K rate, application time and crop sequence, 1984.

Treatment	Head dry matter (%)	Plant			
		Fresh wt (g)	Dry wt (g)	Dry matter (%)	No. ($1000 \cdot ha^{-1}$)
Location (L)					
Gainesville	9.09	735	102	14.9	33.2
Quincy	9.94	770	94.1	12.6	34.3
Significance[z]	**	NS	NS	***	*
Irrigation (I)					
Overhead	9.08	833	110	13.5	34.3
Drip	9.83	669	87.3	14.3	33.0
Significance	*	*	*	*	NS
N-K rate (R) ($kg \cdot ha^{-1}$)					
135-202	9.69	690	94.4	14.6	33.8
270-404	9.22	811	103	13.2	33.5
Significance	***	**	NS	***	NS
LxIxR	NS	NS	NS	**	NS
Time (T)					
Fall + fall	8.68	939	116	12.5	33.6
Fall + spring	10.2	562	81.8	15.4	33.7
Significance	***	***	***	***	NS
LxT	***	NS	NS	**	**
IxT	***	**	*	***	NS
RxT	*	NS	NS	NS	NS
LxIxRxT	NS	NS	NS	NS	*
Sequence (S)					
Br-Tm-Br	9.54	781	103	13.8	33.5
Br-Sq-Br	9.38	720	94.8	14.0	33.8
Significance	NS	NS	NS	NS	NS
RxS	NS	**	*	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

and was higher with residual fall + spring than with fall + fall fertilization. However, time of application interacted with location, irrigation method and N-K rate. At each location, broccoli head dry matter percentage was higher with fall + spring than with fall + fall application time but the difference in values was greater at Gainesville (Table 4-178). With fall + fall N-K application, irrigation method did not affect head dry matter percentage, but with fall + spring fertilization, dry matter percentage was higher with drip than with overhead irrigation (Table 4-179). Rate of fall + fall N-K application did not influence broccoli head dry matter percentage but with fall + spring fertilization, dry matter percentage decreased with an increase in N-K rate. Broccoli head dry matter percentage was not affected by crop sequence (Table 4-177).

Broccoli plant fresh weight was not influenced by location, but was higher with overhead than with drip irrigation. Fresh weight increased with N-K rate and was higher with fall + fall than with fall + spring application time but irrigation method and time interacted to affect plant fresh weight (Table 4-180). With fall + fall N-K application, fresh weights were similar with each irrigation method but with fall + spring fertilization, plant fresh weight was lower with drip than with overhead irrigation. Fresh weight was not affected by crop sequence but N-K rate and sequence interacted in their effect on broccoli plant fresh weight (Table 4-181). Fresh weight of broccoli plant following tomato increased with N-K rate, but rate of N-K application did not affect broccoli plant fresh weight after squash.

Table 4-178. Broccoli head and plant dry matter percentages as affected by location x application time interaction.

Time	Head		Plant	
	Gainesville	Quincy	Gainesville	Quincy
	Dry matter (%)			
Fall + fall	7.96	9.63	13.1	11.6
Fall + spring	10.2	10.3	16.7	13.6
	***[z]	*	***	***

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-179. Broccoli head dry matter percentage as affected by irrigation method x application time and N-K rate x application time interactions.

Time	Irrigation		N-K rate ($kg \cdot ha^{-1}$)	
	Overhead	Drip	135-202	270-404
	Dry matter (%)			
Fall + fall	8.85	8.52NS[z]	8.75	8.62NS
Fall + spring	9.32	11.1 ***	10.6	9.82*
	NS	***	***	***

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-180. Broccoli plant fresh weight, dry weight and dry matter percentage as affected by irrigation method x application time interaction.

Irrigation	Fresh wt (g)		Dry wt (g)		Dry matter (%)	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring	Fall + fall	Fall + spring
Overhead	955	711***[z]	121	98.6**	12.9	14.1*
Drip	923	412***	110	65.1***	12.1	16.6***
	NS	***	NS	***	NS	***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-181. Broccoli plant fresh weight, dry weight and stand as affected by N-K rate x crop sequence interaction.

N-K rate ($kg \cdot ha^{-1}$)	Fresh wt (g)		Dry wt (g)		No. ($1000 \cdot ha^{-1}$)	
	Br-Tm-Br	Br-Sq-Br	Br-Tm-Br	Br-Sq-Br	Br-Tm-Br	Br-Sq-Br
135-202	656	724NS[z]	91.1	97.6NS	34.1	33.5NS
270-404	905	717*	114	92.0*	32.9	34.1*
	**	NS	*	NS	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Plant dry weight was not affected by location but was higher with overhead than with drip irrigation (Table 4-177). Dry weight was not influenced by N-K rate but wes higher with fall + fall than with residual fall + spring N-K application. However, irrigation method interacted with time to affect plant dry weight (Table 4-180). With fall + fall fertilization, plant dry weights were similar with overhead and drip irrigation but with fall + spring nutrient application, dry weight was higher with overhead than with drip irrigation. Broccoli plant dry weight was not affected by crop sequence but was influenced by an N-K rate x sequence interaction (Table 4-181). With the Br-Tm-Br sequence, plant dry weight increased with an increase in N-K rate but with the Br-Sq-Br sequence, N-K rate did not affect broccoli plant dry weight.

Broccoli plant dry matter percentage was higher at Gainesville than at Quincy and with drip than with overhead irrigation (Table 4-177). Dry matter percentage was lower with the higher of the 2 N-K rates but location, irrigation method and N-K rate interacted in their influence on plant dry matter percentage (Table 4-182). At Gainesville with overhead irrigation and at Quincy with drip, dry matter percentage decreased with an increase in N-K rate but at Gainesville with drip and at Quincy with overhead irrigation, N-K rate did not influence broccoli plant dry matter percentage. Dry matter percentage was higher with fall + spring than with fall + fall fertilization but was influenced by a location x time interaction (Table 4-178). At both locations, dry matter percentage was higher with residual fall + spring than fall + fall nutrient application but

Table 4-182. Broccoli plant dry matter percentage as affected by location x irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Overhead	Drip	Overhead	Drip
		Dry matter (%)		
135-202	15.5	16.0NS[z]	12.3	13.9**
270-404	13.1	14.9**	12.4	11.7NS
	**	NS	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

the difference was greater at Gainesville than at Quincy. Irrigation method and application time also interacted to affect broccoli plant dry matter percentage (Table 4-180). With fall + fall fertilization, values were similar with each irrigation method but with fall + spring N-K application, plant dry matter percentage was higher with drip than with overhead irrigation. Crop sequence did not affect dry matter percentage of broccoli plants (Table 4-177).

The number of plants$\cdot ha^{-1}$ was higher at Quincy than at Gainesville but was not affected by irrigation method, N-K rate or time of application. However, all these variables interacted to influence broccoli plant stand at harvest (Table 4-183). At Gainesville with fall + fall applied N-K with the higher rate and with fall + spring fertilization with the lower N-K rate, the number of plants was higher with overhead than with drip irrigation. Irrigation method did not affect plant population with any other location x N-K rate x time treatment combination. The number of plants was similar with either crop sequence but N-K rate and sequence interacted in their effect on plant number (Table 4-181). With the Br-Tm-Br sequence, the number of plants$\cdot ha^{-1}$ decreased with an increase in N-K rate, but with the Br-Sq-Br sequence, N-K rate did not influence plant stand.

Gainesville Soil Analyses

Soil pH was not influenced by irrigation method but decreased with an increase in N-K rate (Table 4-184). Time of N-K application did not affect pH, but irrigation method and time interacted in their

Table 4-183. Broccoli plant stand as affected by location x irrigation method x N-K rate x application time interaction.

Time and N-K rate ($kg \cdot ha^{-1}$)	Gainesville		Quincy	
	Overhead	Drip	Overhead	Drip
	No. ($1000 \cdot ha^{-1}$)			
Fall + fall				
135-202	34.3	33.8NS[z]	34.8	33.0NS
270-404	34.4	31.6**	33.3	33.8NS
	NS	NS	NS	NS
Fall + spring				
135-202	34.1	31.3*	35.0	35.0NS
270-404	34.0	32.0NS	34.8	34.8NS
	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-184. Soil chemical characteristics after broccoli at Gainesville as affected by irrigation method, N-K rate, application time, crop sequence, bed location and soil depth, 1984.

Treatment	pH	EC ($dS \cdot m^{-1}$)	Soil concn (ppm) NO_3-N	NH_4-N	P	K	Ca	Mg
Irrigation (I)								
Overhead	6.34	2.20	15.8	2.48	0.98	49.7	28.0	4.45
Drip	6.53	0.76	3.20	0.74	0.92	8.81	21.4	3.60
Significance[z]	NS	*	*	NS	NS	**	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)								
135-202	6.51	1.15	7.24	1.36	0.94	18.3	21.2	3.48
270-404	6.37	1.80	11.7	1.86	0.96	40.2	28.2	4.57
Significance	***	***	*	NS	NS	***	*	NS
IxR	**	**	NS	NS	NS	**	NS	NS
Time (T)								
Fall + fall	6.45	1.79	12.2	2.13	1.01	40.5	26.4	4.22
Fall + spring	6.42	1.17	6.78	1.08	0.89	18.0	23.0	3.83
Significance	NS	***	**	*	**	***	NS	NS
IxT	***	**	*	*	NS	**	***	**
RxT	NS	NS	NS	NS	NS	NS	**	**
Sequence (S)								
Br-Tm-Br	6.45	1.47	9.65	1.43	0.94	30.8	23.3	3.85
Br-Sq-Br	6.43	1.48	9.31	1.79	0.96	27.7	26.1	4.19
Significance	NS	NS	NS	NS	NS	NS	NS	NS
IxRxS	**	NS	NS	NS	NS	NS	**	**
RxTxS	NS	NS	NS	NS	*	NS	*	NS
Location (L)								
Center	6.45	1.90	10.9	2.26	1.07	49.0	24.7	4.05
Side	6.43	1.06	8.12	0.95	0.83	9.41	24.7	4.00
Significance	NS	***	NS	**	***	***	NS	NS
IxL	***	***	**	**	***	***	***	**
IxRxL	NS	NS	NS	NS	*	**	NS	NS
TxL	NS	NS	NS	NS	*	***	NS	NS
IxTxL	NS	**	NS	*	NS	**	**	**
TxSxL	NS	NS	*	NS	NS	NS	NS	NS
RxTxSxL	***	NS	NS	NS	NS	NS	NS	NS
Depth (D) (cm)								
0-10	6.56	2.38	12.6	2.31	0.93	55.4	32.0	5.52
10-20	6.54	1.18	8.61	1.30	1.02	18.5	27.5	4.30
20-30	6.22	0.88	7.29	1.22	0.90	13.8	14.6	2.25
Significance	***	***	NS	NS	NS	***	***	***
IxD	*	***	NS	NS	NS	***	*	***
RxD	NS	NS	NS	NS	NS	*	NS	NS
IxLxD	NS	***	NS	*	NS	***	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

effect on soil pH (Table 4-185). With fall + fall fertilization, irrigation method did not affect soil pH but with residual fall + spring application, pH was lower with overhead than with drip irrigation. Soil pH was similar with either crop sequence but irrigation method, N-K rate and sequence interacted to affect pH at Gainesville (Table 4-186). With the Br-Tm-Br sequence with overhead irrigation and with the Br-Sq-Br sequence with drip irrigation, soil pH decreased with an increase in N-K rate. With the Br-Tm-Br sequence with drip irrigation or with the Br-Sq-Br sequence with overhead irrigation, N-K rate did not influence soil pH. At Gainesville, soil pH was similar at the center and side of the bed, but irrigation method and location interacted in their effect on pH (Table 4-187). With overhead irrigation, soil pH was higher at the side than at the center of the bed but with drip irrigation pH was higher at the center than the side of the bed. Rate of N-K, time of application, crop sequence and bed location interacted to affect soil pH (Table 4-188). With fall + fall N-K application with the Br-Tm-Br sequence at the side of the bed and with the Br-Sq-Br sequence at the bed center, and with fall + spring fertilization with the Br-Tm-Br sequence at the center of the bed, pH decreased with an increase in N-K rate. Rate of N-K did not influence soil pH with any other sequence x time x bed location combination of treatments. Soil pH decreased as soil depth increased but irrigation method and depth interacted in their effect on soil pH (Table 4-189). With overhead irrigation, pH increased slightly from 0-10 to 10-20 cm, then

Table 4-185. Soil pH and NO_3-N concentration as affected by irrigation method x application time interaction.

Irrigation	pH		NO_3-N (ppm)	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
Overhead	6.41	6.28**[z]	20.6	11.0*
Drip	6.50	6.56NS	3.8	2.6NS
	NS	***	***	***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-186. Soil pH and Ca and Mg concentrations as affected by irrigation method x N-K rate x crop sequence interaction.

Sequence and N-K rate ($kg \cdot ha^{-1}$)	pH		Ca (ppm)		Mg (ppm)	
	Overhead	Drip	Overhead	Drip	Overhead	Drip
Br-Tm-Br						
135-202	6.40	6.61	21.9	33.8	3.44	2.99
270-404	6.29	6.50	32.3	24.1	5.38	3.61
	**	NS	NS	NS	NS	NS
Br-Sg-Br						
135-202	6.36	6.65	17.0	12.2	5.29	2.22
270-404	6.32	6.37	21.8	34.5	3.69	5.58
	NS	***	NS	***	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-187. Soil pH and NO_3-N concentration as affected by irrigation method x bed location interaction.

Location	pH		NO_3-N (ppm)	
	Overhead	Drip	Overhead	Drip
Center	6.29	6.60***[z]	19.7	2.0***
Side	6.40	6.46NS	11.8	4.4***
	**	**	NS	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-188. Soil pH as affected by N-K rate x application time x crop sequence x bed location interaction.

Sequence and N-K rate ($kg \cdot ha^{-1}$)	Fall + fall		Fall + spring	
	Center	Side	Center	Side
		pH		
Br-Tm-Br				
135-202	6.50	6.52NS[z]	6.60	6.40*
270-404	6.41	6.36NS	6.36	6.43NS
	NS	*	*	NS
Br-Sq-Br				
135-202	6.60	6.55NS	6.44	6.44NS
270-404	6.29	6.41NS	6.38	6.31NS
	***	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level.

Table 4-189. Soil pH and Ca and Mg concentrations as affected by irrigation method x soil depth interaction.

Depth (cm)	pH		Ca (ppm)		Mg (ppm)	
	Overhead	Drip	Overhead	Drip	Overhead	Drip
0-10	6.43	6.69	42.3	21.8	7.27	3.77
10-20	6.47	6.60	27.3	27.7	4.00	4.61
20-30	6.14	6.30	14.5	14.7	2.08	2.42
	L***Q***[z]	L***Q**	L***	NS	L***	NS

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

decreased from 10-20 to 20-30 cm. With drip irrigation soil pH decreased from 0-10 to 10-20 cm and from 10-20 to 20-30 cm. With both irrigation methods, the response to increasing soil depth was quadratic. Soil EC was significantly higher with overhead than with drip irrigation and increased with N-K rate but irrigation method and N-K rate interacted (Table 4-190). With both N-K rates, soil EC was higher with overhead than with drip irrigation. With each irrigation method, soil EC increased with an increase in N-K rate but the rate of increase was greater with overhead than with drip irrigation. Soil EC was higher with fall + fall than with fall + spring nutrient application time but was not affected by crop sequence (Table 4-184). Soil EC was higher at the center than the side of the bed but irrigation method, time and location interacted to affect EC (Table 4-191). With fall + fall fertilization with overhead irrigation, soil EC was higher at the center than the side of the bed but with drip irrigation EC was higher at the side than at the bed center. With fall + spring nutrient application with overhead irrigation, soil EC was higher at the center than the side but with drip irrigation, values were similar at each location. Soil EC decreased with depth but irrigation method, bed location and soil depth interacted in their effect on EC (Table 4-192). At the center of the bed with overhead irrigation EC decreased quadraticly with an increase in depth but with drip irrigation, values were similar at all depths. At the bed side with overhead irrigation, soil EC did not differ between depths but with drip irrigation, soil EC decreased linearly with an increase in soil depth.

Table 4-190. Soil EC as affected by irrigation method x N-K rate interaction.

N-K rate ($kg \cdot ha^{-1}$)	EC ($dS \cdot m^{-1}$)	
	Overhead	Drip
135-202	1.61	0.69***[z]
270-404	2.79	0.82***
	**	*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-191. Soil EC and NH_4-N, K, Ca and Mg concentrations as affected by irrigation method x application time x bed location interaction.

Time, irrigation, and location	EC ($dS \cdot m^{-1}$)	Soil concn (ppm)			
		NH_4-N	K	Ca	Mg
Fall + fall					
Overhead					
Center	4.08	5.99	126	47.2	7.21
Side	1.40	1.24	10.2	24.0	3.89
	***[z]	**	***	*	*
Drip					
Center	0.66	0.52	10.7	7.55	1.39
Side	1.01	0.78	15.5	27.0	4.39
	***	NS	***	***	***
Fall + spring					
Overhead					
Center	2.21	1.70	51.8	21.1	3.21
Side	1.11	0.99	10.7	19.8	3.49
	*	NS	**	NS	NS
Drip					
Center	0.64	0.85	2.88	23.0	4.39
Side	0.72	0.80	6.58	27.9	4.22
	NS	NS	***	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-192. Soil EC and NH_4-N and K concentrations as affected by irrigation method x bed location x soil depth interaction.

Location and depth (cm)	EC ($dS \cdot m^{-1}$)		NH_4-N (ppm)		K (ppm)	
	Overhead	Drip	Overhead	Drip	Overhead	Drip
Center						
0-10	5.64	0.71***[z]	6.76	0.42*	182	7.49***
10-20	2.26	0.65***	2.71	0.57*	51.2	9.72***
20-30	1.54	0.59**	2.07	1.07NS	33.2	10.4**
	L***Q*	NS	L**	NS	L***Q**	NS
Side						
0-10	2.00	1.15*	0.81	1.23NS	21.9	10.0 *
10-20	1.03	0.78NS	1.30	0.61NS	4.88	8.07*
20-30	0.74	0.66NS	1.22	0.54NS	4.53	7.11**
	NS	L***	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

Soil NO_3-N concentration was higher with overhead than with drip irrigation and increased with an increase in N-K rate (Table 4-184). Soil NO_3-N was higher with the fall + fall than with the fall + spring application time but irrigation method and time interacted in their effect on NO_3-N concentration (Table 4-185). With either time of nutrient application, soil NO_3-N concentration was higher with overhead than with drip irrigation but the difference was much greater with the fall + fall application time. Soil NO_3-N concentrations were similar with either sequence and at either bed location but irrigation method and location interacted to affect soil NO_3-N (Table 4-187). With overhead irrigation, soil NO_3-N concentrations were similar at the center and side of the bed but with drip irrigation, NO_3-N concentration was higher at the side than the center of the bed. Application time, crop sequence and bed location interacted in their influence on soil NO_3-N concentration (Table 4-193). With the Br-Tm-Br sequence with either application time and with the Br-Sq-Br sequence with fall + spring fertilization, soil NO_3-N concentrations were similar at the center and side of the bed. However, with the Br-Sq-Br sequence and fall + fall nutrient application, soil NO_3-N concentration was higher at the center than at the side of the bed. Soil NO_3-N concentrations were similar at all depths (Table 4-184).

At Gainesville, soil NH_4-N concentration was not affected by irrigation method or N-K rate, but was higher with fall + fall than with fall + spring fertilization. Crop sequence did not affect soil NH_4-N concentration. Soil NH_4-N concentration was higher at the center than at the side of the bed but was influenced by an irrigation

Table 4-193. Soil NO_3-N as affected by application time x crop sequence x bed location interaction.

Location	Br-Tm-Br		Br-Sq-Br	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
		NO_3-N (ppm)		
Center	10.7	5.76NS[z]	18.2	8.76NS
Side	15.9	6.27*	4.0	6.34NS
	NS	NS	**	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

method x application time x bed location interaction (Table 4-191). With fall + fall N-K application with overhead irrigation, soil NH_4-N concentration was higher at the center than the side of the bed but with drip irrigation or with fall + spring fertilization with either irrigation method, NH_4-N concentrations were similar at the center and the side. Soil NH_4-N concentration was not influenced by soil depth but irrigation method, bed location and depth interacted in their effect on NH_4-N concentration (Table 4-192). At the center of the bed with overhead irrigation, NH_4-N concentration decreased linearly with an increase in soil depth but with drip at the center or with either irrigation method at the side, soil NH_4-N concentration was not affected by depth.

Soil P concentration was not affected by irrigation method or N-K rate but was higher with fall + fall than with residual fall + spring N-K application (Table 4-184). Crop sequence did not influence soil P concentration but N-K rate, time and sequence interacted in their effect on soil P concentration (Table 4-194). With the Br-Tm-Br sequence with either N-K rate and with the Br-Sq-Br sequence with the lower N-K rate, soil P concentration was not affected by application time but with the higher N-K rate, soil P concentration was higher with fall + fall than with residual fall + spring time of application. Soil P concentration was higher at the center than at the side of the bed but was influenced by an irrigation method x N-K rate x location interaction (Table 4-195). With overhead irrigation with either N-K rate, soil P concentrations were similar at the center and the side of the bed but with drip irrigation with each N-K rate,

Table 4-194. Soil P and Ca concentrations as affected by N-K rate x application time x crop sequence interaction.

Sequence and N-K rate ($kg \cdot ha^{-1}$)	P (ppm)		Ca (ppm)	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
Br-Tm-Br				
135-202	1.07	0.88NS[z]	24.4	14.5*
270-404	0.94	0.89NS	29.9	24.3NS
	NS	NS	NS	*
Br-Sq-Br				
135-202	0.90	0.90NS	31.2	14.7*
270-404	1.15	0.87*	20.3	38.4*
	NS	NS	NS	**

[z] Effects were not significant (NS) or significant at the 5% (*) or 1% (**) level.

Table 4-195. Soil P and K concentrations as affected by irrigation method x N-K rate x bed location interaction.

Irrigation and location	P (ppm)		K (ppm)	
	135-202	270-404	135-202	270-404
Overhead				
Center	0.90	1.14NS[z]	54.8	123 NS
Side	1.00	0.89NS	6.24	14.6*
	NS	NS	**	***
Drip				
Center	1.14	1.02NS	7.38	11.1*
Side	0.71	0.73NS	4.72	12.1***
	***	***	*	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

soil P concentration was higher at the center than the side. Irrigation method and application time interacted to affect soil P concentration (Table 4-196). With either time of N-K application, soil P concentration was higher at the center than at the side but the difference was greater with the fall + fall application time.

Soil K concentration was significantly higher with overhead than with drip irrigation (Table 4-184). Soil K concentration increased with N-K rate and was higher with fall + fall than with fall + spring fertilization but was not influenced by crop sequence. Soil K concentration was higher at the bed center than at the side, but was influenced by an irrigation method x N-K rate x location interaction (Table 4-195). With overhead irrigation with either N-K rate and with drip irrigation with the 135-202 $kg \cdot ha^{-1}$ rate, soil K concentration was higher at the center than at the side of the bed but with drip irrigation with the higher rate, soil K concentrations were similar at the center and side. Irrigation method, application time and bed location interacted in their effect on soil K concentration (Table 4-191). With overhead irrigetion with either time of application, soil K concentration was higher at the bed center than at the side but with drip irrigation with either application time, the opposite effect occurred. Soil K concentration decreased with an increase in soil depth but N-K rate and depth interacted to affect K concentration (Table 4-197). With the lower N-K rate, soil K concentrations did not differ between depths. However, with the higher N-K rate, soil K concentration decreased significantly from 0-10 to 10-20 cm, and slightly from 10-20 to 20-30 cm. Irrigation method, bed location and

Table 4-196. Soil P concentration as affected by application time x bed location interaction.

Location	P (ppm)	
	Fall + fall	Fall + spring
Center	1.18	0.95
Side	0.84	0.82
	***[z]	*

[z] Effects were significant at the 5% (*) or 0.1% (***) level.

Table 4-197. Soil K concentration as affected by N-K rate x soil depth interaction.

Depth (cm)	K (ppm)	
	135-202	270-404
0-10	33.8	77.0*[z]
10-20	12.8	24.1NS
20-30	8.2	19.4**
	NS	L***Q*

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L) or quadratic (Q).

soil depth interacted to influence soil K concentration (Table 4-192). At the center of the bed with overhead irrigation, soil K concentration decreased quadraticly with the greater difference in K value occurring between the 0-10 and 10-20 cm depths. At the center with drip or at the side of the bed with either irrigation method, soil K concentrations did not differ between soil depths.

Soil Ca concentration was not affected by irrigation method but increased with N-K rate (Table 4-184). Soil Ca concentrations were similar with either nutrient application time and with either crop sequence, but irrigation method, N-K rate and sequence interacted in their effect on soil Ca concentration (Table 4-186). With the Br-Tm-Br sequence with either irrigation method and with the Br-Sq-Br sequence with overhead irrigation, N-K rate did not affect soil Ca concentration. However, with the Br-Sq-Br sequence with drip irrigation, soil Ca concentration increased with N-K rate. Soil Ca concentration was influenced by an N-K rate x application time x crop sequence interaction (Table 4-194). With either sequence, rate of fall + fall applied N-K did not affect soil Ca concentration, but with fall + spring fertilization with either crop sequence, soil Ca concentration increased with N-K rate. Soil Ca concentration was not affected by bed location but irrigation method, application time and location interacted (Table 4-191). With fall + fall N-K application with overhead irrigation, soil Ca concentration was higher at the center than the side location but with drip irrigation, the concentration was higher at the side than at the bed center. With fall + spring fertilization and either irrigation method, soil Ca

concentrations were similar at the center and side of the bed. Soil Ca concentration varied with depth but irrigation method and depth combined to affect Ca concentration (Table 4-189). With overhead irrigation, soil Ca concentration decreased linearly with an increase in depth but with drip irrigation, Ca values did not differ between depths.

Soil Mg concentration was not affected by irrigation method, N-K rate or application time (Table 4-184). However, N-K rate and time interacted in their effect on Mg concentration (Table 4-198). Rate of fall + fall applied N-K did not affect soil Mg concentration but with residual fall + spring nutrient application, soil Mg concentration increased with an increase in N-K rate. Soil Mg concentration was not influenced by crop sequence but was affected by an irrigation method x N-K rate x sequence interaction (Table 4-186). With the Br-Tm-Br sequence with either irrigation method and with the Br-Sq-Br sequence with overhead irrigation, soil Mg concentration was not affected by N-K rate but with the Br-Sq-Br sequence with drip irrigation, soil Mg concentration increased with an increase in N-K rate. The concentration of Mg was similar at the side and center of the bed but irrigation method, application time and location interacted in their effect on soil Mg concentration (Table 4-191). With fall + fall fertilization with overhead irrigation, soil Mg concentration was higher at the center than the side of the bed, but with drip irrigation the concentration was higher at the side than the center. With fall + spring nutrient application with either irrigation method, values were similar at each bed location. Soil Mg concentration

Table 4-198. Soil Mg concentration as affected by N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Mg (ppm)	
	Fall + fall	Fall + spring
135-202	4.51	2.45
270-404	3.93	5.20
	NS[z]	***

[z] Effects were not significant (NS) or significant at the 0.1% (***) level.

decreased with an increase in soil depth but irrigation method and depth interacted to affect Mg concentration (Table 4-189). With overhead irrigation, soil Mg concentration decreased linearly with an increase in depth but with drip irrigation Mg concentrations did not differ between depths.

Quincy Soil Analyses

At Quincy, irrigation method did not influence any soil parameter (Table 4-199). Soil pH decreased with an increase in N-K rate and was not affected by application time but irrigation method, N-K rate and application time interacted in their effect on soil pH (Table 4-200). With overhead irrigation with either application time and with drip irrigation with fall + fall fertilization, soil pH decreased with an increase in N-K rate but with drip irrigation with fall + spring nutrient application, soil pH was not affected by N-K rate. With either crop sequence, pH values were similar but irrigation method, application time and sequence interacted to influence soil pH (Table 4-201). With fall + fall fertilization with overhead irrigation, soil pH was higher with the Br-Sq-Br sequence than with the Br-Tm-Br sequence but with any other time x irrigation method combination, crop sequence did not affect soil pH. Soil pH was higher at the side than at the center of the bed, and decreased with an increase in soil depth (Table 4-199).

Soil EC increased with N-K rate and was higher with fall + fall than with residual fall + spring nutrient application but was not affected by crop sequence. However, irrigation method and sequence interacted to affect soil EC (Table 4-202). With the Br-Tm-Br

Table 4-199. Soil chemical characteristics after broccoli at Quincy as affected by irrigation method, N-K rate, application time, crop sequence, bed location and soil depth, 1984.

Treatment	pH	EC ($dS \cdot m^{-1}$)	Soil concn (%) NO_3-N	NH_4-N	P	K	Ca	Mg
Irrigation (I)								
Overhead	5.81	0.53	1.85	0.55	0.65	9.62	6.08	2.18
Drip	5.73	0.55	2.08	0.61	0.58	8.83	5.55	1.74
Significance[z]	NS	NS	NS	NS	NS	NS	NS	NS
N-K rate (R) ($kg \cdot ha^{-1}$)								
135-202	5.94	0.51	1.53	0.47	0.59	6.97	5.92	2.04
270-404	5.60	0.57	2.40	0.68	0.63	11.5	5.71	1.88
Significance	***	**	**	***	NS	***	NS	NS
Time (T)								
Fall + fall	5.74	0.63	2.87	0.65	0.64	13.4	6.48	2.15
Fall + spring	5.80	0.46	1.07	0.51	0.59	5.03	5.15	1.77
Significance	NS	***	***	**	NS	***	*	NS
IxRxT	***	NS	NS	NS	NS	NS	NS	NS
Sequence (S)								
Br-Tm-Br	5.74	0.54	2.07	0.60	0.58	9.31	5.80	1.87
Br-Sq-Br	5.80	0.54	1.86	0.56	0.64	9.14	5.83	2.05
Significance	NS	NS	NS	NS	NS	NS	NS	NS
IxS	NS	**	NS	NS	NS	***	NS	NS
IxTxS	***	NS	NS	NS	NS	**	NS	NS
IxRxTxS	NS	NS	**	NS	NS	**	NS	NS
Location (L)								
Center	5.69	0.54	2.04	0.62	0.70	11.6	5.00	1.46
Side	5.85	0.55	1.89	0.54	0.52	6.85	6.63	2.45
Significance	***	NS	NS	NS	***	***	***	***
IxRxTxL	NS	*	*	*	**	**	NS	NS
SxL	NS	NS	NS	NS	*	*	NS	NS
RxSxL	NS	NS	NS	NS	NS	*	NS	NS
Depth (D) (cm)								
0-10	5.83	0.60	2.21	0.61	0.93	8.61	7.28	2.68
10-20	5.81	0.49	1.43	0.52	0.58	8.19	4.77	1.58
20-30	5.67	0.54	2.25	0.61	0.33	10.9	5.39	1.62
Significance	**	***	NS	NS	***	**	***	***
LxD	NS	NS	*	NS	NS	*	NS	NS
IxRxLxD	NS	NS	NS	NS	NS	NS	*	**
TxLxD	NS	NS	*	NS	NS	NS	NS	NS
IxRxTxLxD	NS	NS	NS	NS	***	NS	NS	NS
IxSxLxD	NS	NS	NS	*	NS	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-200. Soil pH as affected by irrigation method x N-K rate x application time interaction.

N-K rate ($kg \cdot ha^{-1}$)	Overhead		Drip	
	Fall + fall	Fall + spring	Fall + fall	Fall + spring
		pH		
135-202	5.96	6.12NS[z]	5.82	5.87NS
270-404	5.72	5.42***	5.45	5.80***
	**	***	***	NS

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-201. Soil pH as affected by irrigation method x application time x crop sequence interaction.

Sequence	Fall + fall		Fall + spring	
	Overhead	Drip	Overhead	Drip
		pH		
Br-Tm-Br	5.73	5.64	5.83	5.76
Br-Sq-Br	5.96	5.62	5.71	5.91
	**[z]	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 1% (**) level.

Table 4-202. Soil EC as affected by irrigation method x crop sequence interaction.

Sequence	EC ($dS \cdot m^{-1}$)	
	Overhead	Drip
Br-Tm-Br	0.51	0.58*[z]
Br-Sq-Br	0.56	0.53NS
	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level.

sequence, soil EC was higher with drip than with overhead irrigation but with the Br-Sq-Br sequence, irrigation method did not influence soil EC. Soil EC was similar at the center and side bed locations, but was affected by an irrigation method x N-K rate x application time x bed location interaction (Table 4-203). With fall + fall ferilization with either irrigation method at the bed center, N-K rate did not influence soil EC. At the side location with overhead irrigation, EC decreased with an increase in N-K rate but with drip irrigation, soil EC increased with N-K rate. With residual fall + spring N-K application with overhead irrigation at each bed location, EC values were similar with both N-K rates but with drip irrigation at each location, soil EC increased with N-K rate. Soil EC decreased from 0-10 to 10-20 cm, then increased slightly from 10-20 to 20-30 cm (Table 4-199).

Soil NO_3-N concentration increased with N-K rate and was higher with fall + fall than with fall + spring fertilization, but was not affected by crop sequence. However, irrigation method, N-K rate, application time and sequence interacted in their effect on soil NO_3-N concentration (Table 4-204). With the fall + fall application time with overhead irrigation with the Br-Tm-Br sequence and with drip irrigation with the Br-Sq-Br sequence, and with fall + spring fertilization with drip irrigation with either crop sequence, N-K rate did not affect soil NO_3-N concentration. However, with fall + fall fertilization with drip irrigation with the Br-Tm-Br sequence and with overhead irrigation with the Br-Sq-Br sequence, and with fall + spring N-K application with overhead irrigation with either sequence, soil

Table 4-203. Soil EC and NO_3-N, NH_4-N and K concentrations as affected by irrigation method x N-K rate x application time x bed location interaction.

Time, irrigation and N-K rate ($kg \cdot ha^{-1}$)	EC ($dS \cdot m^{-1}$)		NO_3-N (ppm)		NH_4-N (ppm)		K (ppm)	
	Center	Side	Center	Side	Center	Side	Center	Side
Fall + fall								
Overhead								
135-202	0.63	0.64NS[z]	2.56	2.26NS	0.42	0.44NS	15.4	8.37***
270-404	0.72	0.51*	4.67	1.58*	0.96	0.50NS	24.7	7.04***
	NS	*	NS	NS	NS	NS	NS	NS
Drip								
135-202	0.56	0.54NS	1.79	1.75NS	0.69	0.56NS	13.1	5.8***
270-404	0.63	0.80*	3.17	5.35NS	0.82	0.78NS	17.8	15.2NS
	NS	**	NS	*	NS	*	**	***
Fall + spring								
Overhead								
135-202	0.44	0.42NS	0.94	0.66NS	0.44	0.41NS	4.74	2.89***
270-404	0.42	0.48NS	1.17	1.24NS	0.60	0.60NS	7.14	6.61NS
	NS	NS	NS	**	NS	***	**	***
Drip								
135-202	0.42	0.44NS	1.20	1.10NS	0.39	0.44NS	2.91	2.47NS
270-404	0.46	0.55*	1.14	1.14NS	0.63	0.60NS	6.92	6.56NS
	*	**	NS	NS	**	NS	***	***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

Table 4-204. Soil NO_3-N and K concentrations as affected by irrigation method x N-K rate x application time x crop sequence interaction.

Sequence and N-K rate ($kg \cdot ha^{-1}$)	Fall + Fall		Fall + spring	
	Overhead	Drip	Overhead	Drip
		NO_3-N (ppm)		
Br-Tm-Br				
135-202	3.32	1.93NS[z]	0.70	1.23***
270-404	1.75	5.24*	1.20	1.11NS
	NS	*	**	NS
Br-Sq-Br				
135-202	1.50	1.59NS	0.90	1.07NS
270-404	4.17	3.28NS	1.21	1.16NS
	*	NS	*	NS
		K (ppm)		
Br-Tm-Br				
135-202	12.9	11.1NS	3.52	3.20NS
270-404	10.1	19.7***	6.56	7.39NS
	NS	***	***	***
Br-Sq-Br				
135-202	10.9	7.9NS	4.11	2.18***
270-404	21.7	13.2NS	7.19	6.08NS
	*	**	***	***

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level.

NO_3-N concentration increased with an increase in N-K rate. Soil NO_3-N concentrations were similar at both bed locations but irrigation method, N-K rate, application time and bed location interacted to affect soil NO_3-N concentration (Table 4-203). At the bed center with either application time with overhead or drip irrigation and at the side of the bed with fall + fall application with overhead irrigation or with fall + spring fertilization with drip irrigation, N-K rate did not influence soil NO_3-N concentration. However, at the side of the bed with fall + fall N-K application with drip irrigation and with fall + spring fertilization with overhead irrigation, soil NO_3-N concentration increased with an increase in N-K rate. Soil NO_3-N concentrations were similar at all depths but application time, bed location and soil depth interacted in their effect on soil NO_3-N (Table 4-205). With fall + fall fertilization at the bed center, soil NO_3-N concentration increased linearly with soil depth. With fall + fall N-K application at the side of the bed and with fall + spring fertilization at either bed location, soil NO_3-N concentrations did not differ between depths.

Soil NH_4-N concentration increased with N-K rate and was higher with fall + fall than fall + spring nutrient application, but was not affected by crop sequence or bed location (Table 4-199). However, irrigation method, N-K rate, application time and location interacted in their effect on NH_4-N concentration (Table 4-203). At the center of the bed with fall + spring fertilization with drip irrigation and at the side location with both fall + fall application with drip irrigation and fall + spring fertilization with overhead irrigation,

soil NH_4-N concentration increased with N-K rate but N-K rate did not affect soil NH_4-N concentration with any other location x application time x irrigation method combination. Soil NH_4-N concentration was not influenced by depth but was affected by an irrigation method x crop sequence x location x depth interaction (Table 4-206). At the side of the bed with the Br-Sq-Br sequence with drip irrigation, soil NH_4-N concentration increased linearly with an increase in soil depth. Soil NH_4-N concentrations were similar at all depths with all other location x sequence x irrigation method combinations.

Soil P concentration was not influenced by N-K rate, application time or crop sequence, but was higher at the center than at the side of the bed (Table 4-199). However, sequence and location interacted to affect soil P (Table 4-207). With the Br-Tm-Br sequence, values were similar at both locations but with the Br-Sq-Br sequence, soil P concentration was higher at the center than the side of the bed. Soil P concentration decreased with an increase in soil depth but was influenced by an irrigation method x N-K rate x application time x bed location x soil depth interaction (Table 4-208). With the lower N-K rate with fall + fall fertilization with both drip irrigation at the bed center and overhead irrigation at the side of the bed, and with the higher N-K rate at the side of the bed with fall + fall N-K application with either irrigation method and with fall + spring fertilization with overhead irrigation, soil P concentration was not affected by soil depth. However, with all other treatment combinations, soil P concentration decreased linearly with increased soil depth.

Table 4-205. Soil NO_3-N concentration as affected by application time x bed location x soil depth interaction.

Depth (cm)	Fall + fall		Fall + spring	
	Center	Side	Center	Side
	NO_3-N (ppm)			
0-10	2.44	4.19	1.25	1.07
10-20	1.85	1.82	1.06	1.02
20-30	4.65	2.30	1.03	1.02
	L*[z]	NS	NS	NS

[z] Effects were not significant (NS) or significant at the 5% (*) level. Effect of depth was linear (L).

Table 4-206. Soil NH_4-N concentration as affected by irrigation method x crop sequence x bed location x soil depth interaction.

Location and depth (cm)	Br-Tm-Br		Br-Sq-Br	
	Overhead	Drip	Overhead	Drip
	NH_4-N (ppm)			
Center				
0-10	0.71	0.60	0.62	0.64
10-20	0.46	0.72	0.48	0.54
20-30	0.56	0.74	0.81	0.55
	NS	NS	NS	NS
Side				
0-10	0.48	0.77	0.58	0.47
10-20	0.44	0.58	0.47	0.47
20-30	0.51	0.58	0.45	0.68
	NS	NS	NS	L*

[z] Effects were not significant (NS) or significant at the 5% (*) level.

Table 4-207. Soil P concentration as affected by crop sequence x bed location interaction.

Location	P (ppm)	
	Br-Tm-Br	Br-Sq-Br
Center	0.62	0.78
Side	0.54	0.51
	NS[z]	**

[z] Effects were not significant (NS) or significant at the 1% (**) level.

Table 4-208. Soil P concentration as affected by irrigation method x N-K rate x application time x bed location x soil depth interaction.

N-K rate ($kg \cdot ha^{-1}$), location, and depth (cm)	Fall + fall		Fall + spring	
	Overhead	Drip	Overhead	Drip
		P (ppm)		
135-202				
Center				
0-10	1.60	0.77	0.68	1.08
10-20	0.85	0.68	0.78	0.43
20-30	0.40	0.43	0.35	0.28
	L**[z]	NS	L*	L**
Side				
0-10	0.65	0.77	0.78	0.82
10-20	0.35	0.42	0.33	0.52
20-30	0.33	0.33	0.25	0.28
	NS	L*	L**	L*
270-404				
Center				
0-10	0.67	1.30	1.18	1.00
10-20	0.72	0.78	0.77	0.62
20-30	0.33	0.30	0.40	0.42
	L***	L***	L*	L**
Side				
0-10	1.53	0.52	0.77	0.78
10-20	0.53	0.43	0.48	0.50
20-30	0.36	0.18	0.38	0.23
	NS	NS	NS	L**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L).

Soil K concentration increased with an increase in N-K rate and was higher with fall + fall than with residual fall + spring nutrient application, but was not affected by crop sequence (Table 4-199). However, irrigation method, N-K rate, application time and crop sequence combined to influence soil K (Table 4-204). With fall + fall fertilization with overhead irrigation with the Br-Tm-Br sequence, soil K concentration was not affected by N-K rate but with all other time x irrigation method x sequence combinations, soil K concentration increased with an increase in N-K rate. Soil K concentration was higher at the center than the side of the bed but irrigation method, N-K rate, time and bed location interacted in their effect on soil K (Table 4-203). Soil K concentration was not affected by rate of fall + fall applied N-K with overhead irrigation at either bed location, but with all other time x irrigation method x location combinations, soil K concentration increased with N-K rate. Crop sequence, N-K rate and bed location also interacted to affect soil K concentration (Table 4-209). At the bed center with the Br-Tm-Pr sequence, soil K concentrations were similar with either N-K rate but at the side with either sequence and at the center with the Br-Tm-Br sequence, soil K concentration was higher with the higher than lower application rate. Soil K concentrations differed between depths but location and depth interacted in their effect on K concentration (Table 4-210). At the bed center, soil K concentration increased with an increase in soil depth but at the side, values were similar at all depths.

Soil Ca concentration was not influenced by N-K rate but was higher with fall + fall than with residual fall + spring N-K

Table 4-209. Soil K concentration as affected by N-K rate x crop sequence x bed location interaction.

N-K rate ($kg \cdot ha^{-1}$)	Br-Tm-Br		Br-Sq-Br	
	Center	Side	Center	Side
		K (ppm)		
135-202	9.7	5.66**[z]	8.4	4.11***
270-404	12.3	9.62NS	16.1	8.01**
	NS	**	**	***

[z] Effects were not significant (NS) or significant at the 1% (**) or 0.1% (***) level.

Table 4-210. Soil K concentration as affected by bed location x soil depth interaction.

Depth (cm)	K (ppm)	
	Center	Side
0-10	10.1	7.13*[z]
10-20	10.3	6.06***
20-30	14.4	7.36***
	L*	NS

[z] Effects were not significant (NS) or significant at the 5% (*) or 0.1% (***) level. Effect of depth was linear (L).

application (Table 4-199). Concentrations were similar with either sequence but soil Ca concentration was higher at the side than at the bed center. Soil Ca concentration varied with soil depth but irrigation method, N-K rate, location and depth interacted to affect Ca concentration (Table 4-211). With overhead irrigation with either N-K rate at either bed location and with drip irrigation with the 270-404 $kg \cdot ha^{-1}$ N-K rate at the side of the bed, soil Ca concentration decreased linearly with an increase in soil depth. However, with drip irrigation with the lower N-K rate at the side of the bed, soil Ca concentration increased linearly with soil depth. With drip irrigation with either application rate at the bed center, Ca concentrations were similar at all soil depths.

Soil Mg concentration was not influenced by N-K rate, application time, or crop sequence but was higher at the side than center of the bed (Table 4-199). Soil Mg concentration decreased from 0-10 to 10-20 cm, then increased slightly from 10-20 to 20-30 cm depth, but irrigation method, N-K rate, bed location and soil depth interacted in their effect on soil Mg concentration (Table 4-211). With overhead irrigation with the lower N-K rate at the bed center, and with drip irrigation with either rate at the bed center and with the lower rate at the side, soil Mg concentrations were similar at all depths. With overhead irrigation with the 135-202 $kg \cdot ha^{-1}$ N-K rate at the side of the bed and with either rate at the bed center, and with drip irrigation with either N-K rate at the side, soil Mg concentrations decreased linearly with an increase in soil depth.

Table 4-211. Soil Ca and Mg concentrations as affected by irrigation method x N-K rate x bed location x soil depth interaction.

Location and depth (cm)	Overhead		Drip	
	135-202	270-404	135-202	270-404
		Ca (ppm)		
Center				
0-10	8.25	8.46NS[z]	4.63	3.33NS
10-20	4.72	4.43NS	3.69	3.46NS
20-30	5.18	3.70NS	4.18	5.98NS
	L*	L**	NS	NS
Side				
0-10	9.32	8.35NS	5.28	10.6 *
10-20	6.68	4.40***	4.98	5.81NS
20-30	5.38	4.06*	8.72	5.96NS
	L**	L*	L*	L**
		Mg (ppm)		
Center				
0-10	2.14	3.25NS	1.73	0.81**
10-20	1.54	1.40NS	1.07	0.75NS
20-30	1.75	1.03NS	1.12	0.98NS
	NS	L**	NS	NS
Side				
0-10	4.14	2.93NS	1.77	4.63NS
10-20	2.83	1.53***	1.63	1.93NS
20-30	2.13	1.45**	2.60	1.89NS
	L***	L*	NS	L**

[z] Effects were not significant (NS) or significant at the 5% (*), 1% (**) or 0.1% (***) level. Effects of depth were linear (L).

CHAPTER 5
DISCUSSION

Crop Yields

Irrigation Method

In 1983, early and total broccoli yields were higher with drip than with overhead irrigation. Late yield and head weight were not influenced by irrigation method. The number of heads produced at Gainesville was higher with drip than with overhead irrigation, but at Quincy, irrigation method did not affect the number of heads produced.

Broccoli yield parameters in 1984 were affected by irrigation method x fertilizer application time interactions. With concurrent fall + fall fertilization, early broccoli yields were similar with either irrigation method. However, different timing of N-K application with the 2 irrigation methods may have influenced early broccoli yields. Overhead irrigated plots received 100% of the scheduled N-K application prior to transplanting but drip fertigated plots received N-K in weekly increments beginning one week after transplanting. With concurrent fertilization, early growth and yields of drip irrigated broccoli probably were reduced due to lower soil N-K concentrations with drip than overhead irrigation. With the residual fall + spring nutrient application early yields were higher with overhead than drip irrigation at Gainesville, and similar with either irrigation method at Quincy. Increased leaching of soil nutrients has

been reported with drip as compared to overhead irrigation resulting in reduced soluble salt concentrations in the soil (37,73). At Gainesville, soil EC following tomatoes and squash averaged 1.72 $dS \cdot m^{-1}$ with overhead irrigation and 0.92 $dS \cdot m^{-1}$ with drip while at Quincy, EC was 0.72 and 0.48 $dS \cdot m^{-1}$, respectively. The greater difference in soluble salt concentration with residual fertilization at Gainesville resulted in a significant increase in yield with overhead irrigation while the similar, low concentrations at Quincy resulted in a similar yield with either irrigation method. With concurrent fall + fall nutrient application, the weekly N-K applications with drip irrigation maintained favorable nutrient levels through harvest, thus reducing the effect of leaching of residual nutrients, resulting in early yield similar to that obtained with overhead irrigation. Late broccoli yield following tomato was not affected by irrigation method with either time of N-K application; however, late yield after squash with drip irrigation was higher than with overhead with concurrent fall + fall fertilization but lower than with overhead with residual fall + spring nutrient application. The higher late yield after squash obtained with drip irrigation with concurrent fertilization was due to the more favorable soil nutrient status later in the season with fertigation. On similar soils with mulched tomatoes, Locascio et al. (60) found higher soil N concentrations at 8 and 12 weeks after transplanting with a fertigation program similar to that used in this study than with 100% preplant fertilization. The lower yield with residual nutrients can be attributed to leaching of soil nutrients with drip irrigation.

Average EC measurements of soil samples taken after squash were 1.48 and 0.81 $dS \cdot m^{-1}$ for overhead and drip irrigation. Total squash yield responded similarly, with higher yield obtained with overhead than drip irrigation with residual nutrient application and similar yields with either irrigation method with concurrent fall + fall fertilization. The number of broccoli heads produced was not influenced by irrigation method with fall + fall fertilization. However, with fall + spring N-K application, the number of broccoli heads produced at Gainesville was higher with overhead than drip irrigation while at Quincy, irrigation method did not affect broccoli head number. Average head fresh weight was higher with drip than with overhead irrigation with fall + fall application time but this response was reversed with fall + spring fertilization. More favorable season-long nutrient availability with drip fertigation than with overhead irrigation produced the former result while leaching of residual soil nutrients by drip irrigation in the absence of fertilization was responsible for the latter.

At Gainesville, early season tomato yield was not affected by irrigation method but mid-season large, marketable and total yields were influenced by irrigation method x fertilizer application time interactions. With N-K applied to fall broccoli only, large, marketable and total mid-season yields of spring tomatoes were higher with overhead than with drip irrigation, but with fall + spring fertilizer application, mid-season yields were not affected by irrigation method. On rocky marl and calcareous soils, large size tomato yields were higher with drip than with overhead irrigation with

concurrent fertilization (15,84). Higher soil soluble salts after fall broccoli with overhead than with drip irrigation contributed to the yield difference with residual fertilization. However, in the drip irrigated residual fertilizer plots, severe infestations of bacterial spot (Xanthamonas vesicatoria (Dodge) Dows.) reduced plant vigor and ultimately, fruit yield. The severe infestation in these plots may have been due to the poorer mineral nutrition as previously discussed. Late season large, medium and total tomato yields and season total large tomato yield responded to irrigation methods in a similar manner for the same reasons.

At Quincy, early and late tomato yields were similar with either irrigation method. However, mid-season and total yields and numbers of marketable and cull and total tomato fruit were higher with overhead than with drip irrigation. Although many researchers have obtained higher tomato yields with drip than with overhead irrigation (15,38,58,84), the opposite effect also has been reported as a result of nutrient leaching by drip irrigation (72). The reduced yield of drip irrigated tomatoes in this study resulted in part from infestation by Sclerotium rolfsii. The spread of this fungal disease is favored by excessive soil moisture. The more severe incidence of this pest in the drip irrigated plots was attributed to the high level of soil moisture maintained by that method of irrigation (67), compounded by several heavy rainfalls and poor field drainage. Drip irrigated tomato yield also may have been reduced as a result of timing of concurrent N-K application. With overhead irrigation, all N-K was applied preplant but with drip irrigation, N-K was applied in

weekly increments beginning 1 week after transplanting. Others have reported yields of drip irrigated tomatoes (60,62) and muskmelon (10), with all or part of the nutrients applied before transplanting, were higher than with fertigation after transplanting. Average fruit weight was not affected by irrigation method at any time.

Early, late and total squash yields and number of fruit were not affected by irrigation method alone, but average fruit weight was higher with overhead than with drip irrigation. With residual fall nutrient application, early and late yields and number of fruit were higher with overhead than with drip irrigation. Soil EC values following fall broccoli production averaged 2.23 and 1.16 $dS \cdot m^{-1}$ for overhead and drip irrigated plots, respectively. The additional leaching of the unfertilized spring squash plots by drip irrigation further reduced soil nutrient levels, and resulted in lower yields than obtained from overhead irrigated plots. With fall + spring N-K application, weekly drip fertigation maintained adequate soil nutrient levels, and yield categories, although slightly higher with drip than with overhead irrigation, did not differ significantly between irrigation methods. However, with overhead irrigation at Gainesville, total yield increased with an increase in rate of fall + spring N-K application while with drip irrigation similar high yields were obtained with either rate of concurrent fertilization. Due to the more favorable levels of soil nutrients throughout the season, high squash yields can be realized with one-half the fertilizers required for similar yields with overhead irrigation on a fine sand soil.

Rate of N-K Application

Early broccoli yields in 1983 were similar with 135-202 or 270-404 kg·ha^{-1} N-K, but late and total yields were higher with the higher of the 2 rates. Increased rate of N application delays broccoli maturity (22) but the opposite response has been found for increased rate of K application (71). Others have reported increased total yields of broccoli in response to increased rates of N up to 242 kg·ha^{-1} (25,42) and K up to 560 kg·ha^{-1} (71). The number of heads and average weight per head also were not affected by N-K rate. However, Letey et al. (52) and Dufault and Waters (25) reported broccoli head weight increased with increasing rate of N while Peck and MacDonald (71) obtained quadratic and linear increases in head weight and number, respectively, with increased K fertilization rate.

In 1984, early broccoli yield at Gainesville with fall + fall time of N-K application and either irrigation method or with fall + spring fertilization with drip irrigation was not affected by N-K rate. However, with residual fall + spring nutrient application with overhead irrigation, early yields of broccoli following tomato or squash increased with an increase in N-K rate. Soil soluble salts with residual nutrients and overhead irrigation averaged 1.10 and 2.08 dS·m^{-1} for the 135-202 and 270-404 kg·ha^{-1} N-K rates, respectively. Others have reported increased yields of unfertilized 2nd crops with increased rates of first crop fertilization due to increased residual soil soluble salts (14). Early broccoli yields at Quincy were similar with either N-K rate except for a slight yield increase with the higher rate for drip irrigated plots following squash. Late yields

were not affected by N-K rate, but total yield response to N-K rate was similar to early yield, which accounted for most of the total yield obtained. Average head weight increased with N-K rate with overhead irrigation at Gainesville, but was not influenced by fertilizer rate with drip irrigation at Gainesville, or either irrigation method at Quincy. Dufault and Waters (25) obtained higher broccoli head weights with increasing N rates to 224 $kg \cdot ha^{-1}$ with overhead irrigation on a loamy sand soil. The number of heads increased at Gainesville with increased rate of residual N-K fertilization, but was not affected by N-K rate with any other location x application time combination. Residual soluble salts following tomato and squash averaged 1.20 and 1.54 $dS \cdot m^{-1}$ for the low and high N-K rates at Gainesville but were similar (0.60 and 0.59 $dS \cdot m^{-1}$) at Quincy.

At Gainesville, early large tomato yield increased with rate of fall fertilization but was not affected by N-K rate with fall + spring application time. Similar findings were reported by Everett (30) for 2nd crop spring tomatoes following fall tomatoes. Soil soluble salts in the unfertilized plots following fall broccoli averaged 1.31 and 2.43 $dS \cdot m^{-1}$ for the 135-202 and 270-404 $kg \cdot ha^{-1}$ N-K rates. Medium, small and total early season tomato yields were similar with either N-K rate. Mid-season large tomato yield was lower with the lower than higher rate with overhead irrigation, but was not affected by N-K rate with drip irrigation. The more timely application of N-K with drip fertigation resulted in high mid-season yields with the lower N-K rate and little benefit was obtained with an increased N-K rate. Medium

size and cull tomato yields were not influenced by rate, but mid-season yield of small tomatoes produced with overhead irrigation and residual nutrients increased with N-K rate. Rate of N-K application did not affect any late season yield category but cumulative yield of large tomatoes was higher with the higher than lower N-K rate. This effect was due to the yield responses to N-K rate for early and mid-season large tomatoes previously discussed.

At Quincy, rate of N-K application did not affect any tomato yield category. Lack of tomato yield response to increased rates of N application above 120, 135 and 148 $kg \cdot ha^{-1}$ on loamy (86), fine loamy sand (23) and fine sand (20) soils, respectively, has been reported.

Early, late and total yield of squash and average weight and number of $fruit \cdot ha^{-1}$ increased with an increase in rate of fall applied N-K. This response was due to the significantly higher residual soil soluble salt concentrations remaining after fall broccoli with the higher N-K rate. However, with concurrent fall + spring fertilization, early yield and number and average weight of fruit were not affected by N-K rate. At Gainesville, late yield increased with N-K rate with fall + spring application and was higher with the higher rate with overhead than with drip irrigation. Total squash yield also increased with an increase in N-K rate with fall + spring fertilization and overhead irrigation at Gainesville. The lack of response of any yield parameter to increased N-K rate at Quincy with concurrent fertilization indicates adequate soil nutrient levels for summer squash production with 135-202 $kg \cdot ha^{-1}$ N-K on a loamy fine sand. Similar responses to rate of nutrient application with

concurrent and residual fertilization of mulched butternut squash following fall tomato production were obtained by Bryan and Dalton (14).

Time of N-K Application

At Gainesville, early season large tomato yield was higher with fall + spring fertilization than with residual fall application at the lower 135-202 $kg \cdot ha^{-1}$ N-K rate. However, with the higher rate of fall applied N-K, early large tomato yield was as high as with fall + spring fertilization at either rate. Early yields of medium and small size tomatoes were similar with either time of N-K application. All mid and late season and total tomato yield categories were higher with concurrent fall + spring fertilization than with fall N-K application. Apparently, residual nutrients from fall fertilization were rapidly depleted, resulting in decreased yields at the later harvest times.

At Quincy, early yield and number of marketable tomato fruit were similar with either time of nutrient application with the lower N-K rate. However, with the higher 270-404 $kg \cdot ha^{-1}$ N-K rate, marketable fruit yield and number were lower with fall + spring than with residual fall fertilization. Others (19) have reported reduced yields when 2nd crops following fall tomatoes were refertilized at spring planting. Excessive soluble salts resulted from 2nd crop fertilization and reduced emergence of direct seeded crops, decreased survival of transplanted crops, and reduced total and per plant yields of surviving crops. This is most likely the effect observed in this study. Soil EC for low and high N-K rates after fall broccoli at

Quincy was 1.34 and 1.69 $dS \cdot m^{-1}$, respectively. The addition of NH_4NO_3 and KCl fertilizers at a high rate in the spring increased soluble salt concentration to a level detrimental to crop production. Early season cull weight and total yield were lower with fall + spring fertilization than with residual fall N-K application. All mid-season yield categories were similar with either application time. Late season yield and number of cull fruit and total fruit yield were higher with fall + spring than with fall nutrient application. Late season and total yields and numbers of marketable fruit produced with the lower N-K rate were higher with fall + spring fertilization but with the higher N-K rate, values were similar with either time of N-K application. High soil soluble salts with 270-404 $kg \cdot ha^{-1}$ N-K applied in both fall and spring probably reduced these parameters. Average marketable fruit weights (large size) at all harvests and total number and weight of cull fruit and total yield were similar with either time of N-K application.

Early, late and total squash yields and number of fruit were higher with fall + spring than with fall nutrient application time. Average fruit weight also was higher with fall + spring than with fall fertilization except with the 270-404 $kg \cdot ha^{-1}$ N-K rate, with overhead irrigation at Gainesville or with either irrigation method at Quincy, average weight of squash fruit was not affected by time of N-K application. The higher levels of residual soil nutrients with the higher rate of fall N-K application at Gainesville with overhead irrigation and at Quincy were adequate for production of marketable size fruit.

Early and total yields and number of heads·ha^{-1} of broccoli in 1984 were higher with concurrent fall + fall than with residual fall + spring fertilization. Late yields of broccoli produced with overhead irrigation were similar with either application time due to the higher average concentrations of residual soil nutrients with that irrigation method. With drip irrigation, residual nutrient concentrations were very low, and late yield was higher with concurrent than residual N-K application. The 3.9 t·ha^{-1} total yield obtained with residual N-K application was similar to values reported by others (19) for nonfertilized, seep irrigated broccoli following fertilized tomato; however, with both crops fertilized, 2nd crop broccoli yield decreased due to a 47% reduction in plant stand caused by high soil soluble salts with consecutive crop fertilization. In this study, plant stand was not affected by time of N-K application, and yield increased to 10.5 t·ha^{-1} with concurrent fertilization. Average head weights also were higher with fall + fall than with fall + spring nutrient application except at Quincy with overhead irrigation where the difference was not significant. This effect was due to the higher concentration of residual soil nutrients with overhead irrigation as compared to drip as well as increased nutrient retention by the slightly heavier soils at Quincy.

Crop Sequence

Early and late yields and number and average weight of broccoli heads were not influenced by crop sequence, but total marketable yield was higher following squash than tomato. The increased concentrations of residual soil nutrients after squash resulted in higher yields than

those after tomato. Saturated paste extract EC measurements averaged 0.77 and 1.15 $dS \cdot m^{-1}$ for soils sampled after tomato and squash, respectively.

Mineral Composition of Plant Tissues

Irrigation Method

In 1983, broccoli leaf N concentrations were not influenced by irrigation method at 4 weeks after transplanting but at 9 weeks with the 270-404 $kg \cdot ha^{-1}$ N-K rate, leaf N concentration was 6.29% with drip irrigation and 5.76% with overhead irrigation. At the earlier sampling time, only 67% of the scheduled N had been applied to the drip irrigated plots and at the later time, 97%, while 100% had been applied to the overhead irrigated plots at planting. The weekly fertigation with drip maintained higher soil N concentrations later in the season which were reflected in the leaf tissue analyses, especially with the higher rate of N-K application. Head and plant N concentrations were similar with either irrigation method. The average broccoli leaf N concentrations of 6.07 and 5.59% at 30 and 60 days after transplanting were higher than the 4.58% N concentration obtained by Magnifico et al. (64) for average leaf N concentration over a 6 month period. The 5.26% average broccoli head N concentration in this study was considerably higher than the 0.8% reported by Magnifico et al. (64).

Broccoli tissue N concentrations in 1984 were higher with drip than with overhead irrigation with concurrent fall + fall N-K application although only leaf tissue sampled 6 weeks after trans-

planting was affected significantly. With residual fall + spring nutrient application, all tissue N concentrations were higher with overhead than with drip irrigation. Soil concentrations of NO_3-N and NH_4-N were lower with drip than with overhead irrigation following both tomato and squash, and probably were reduced further by the leaching associated with drip irrigation. These differences were reflected in the tissue analyses. Plant N concentrations at Quincy with the lower N-K rate were 3.26 and 2.71% with overhead and drip irrigation, but with the higher rate and at Gainesville with either rate, values were not affected by irrigation method.

Average tissue N concentrations in 1984 were lower than in 1983. Half of the plots received no N application in 1984 which greatly reduced average tissue N concentrations.

Leaf N concentrations at 7 weeks after transplanting 4 week old tomato plants were similar with either irrigation method but at 14 weeks leaf N concentration was higher with overhead than with drip irrigation. Holbrooks and Wilcox (39) found that after 10 weeks after seeding, N accumulation by tomato was primarily in the fruit, and leaf and branch N concentrations decreased thereafter. Apparently, the higher concentration of soil N between 7 and 14 weeks after transplanting with the all preplant N-K application with overhead irrigation was reflected in the later leaf tissue samples. By the time that 100% of the scheduled N had been applied in the drip irrigated plots (12 weeks after transplanting), N absorbed by the roots was preferentially partitioned into the fruit, and leaf concentration of N no longer reflected the plant or soil N status.

Late season rainfall at both locations may have combined with the higher soil moisture with drip irrigation to leach N from the root zone and contributed to the lower leaf N concentration obtained with drip irrigation late in the season. Fruit N concentrations, however, were similar with either irrigation method. If N availability in the soil is adequate, the N concentration in plant vegetative parts remains relatively constant, and the N accumulated by the fruit is primarily from the soil. However, if soil nutrient availability is limiting, N required for development is translocated to the fruit from the vegetative portions of the plant (39,91). Thus, only if severe soil nutrient differences are associated with treatments would an effect on fruit N concentration be expected. Plant N concentration at Gainesville with concurrent fall + spring N-K application was not influenced by irrigation method but with residual fall fertilization, N concentration was higher with drip than with overhead irrigation. Fruit yield at Gainesville was lowest with the drip irrigated, residual nutrient treatment. The lower fruit load reduced the sink for translocation of N from the vegetative portion of the plant, and resulted in a higher plant N concentration than with other treatments. At Quincy, plant N concentration was not affected by irrigation method with residual fertilization but was higher with overhead than with drip irrigation with concurrent fall + spring N-K application. The low plant N concentration with drip irrigation with fall + spring fertilization was similar to N concentrations with either irrigation method with residual fall fertilization, so the effect of irrigation probably was due to leaching. Several heavy

rains at Quincy combined with the much higher level of soil moisture maintained by drip irrigation than by overhead irrigation, resulted in the loss of N from the root zone. The ranges of leaf and fruit N concentrations obtained in this study were similar to other studies (39,60,61,62,91) but plant N concentrations were lower. The low plant N concentrations, especially at Quincy were due to lower soil N availability, which resulted from leaching rains at both locations later in the season. More N was translocated from the vegetative parts to the fruit, which reduced average plant N concentrations.

Six weeks after emergence, squash leaf N concentration was similar with either irrigation method but fruit N concentration was 2.82% with overhead irrigation and 2.28% with drip. Only 60% of the scheduled N-K had been applied to the drip irrigated plots by that time, while 100% had been applied to overhead irrigated plots at seeding. Ten weeks after emergence, fruit N concentrations, which averaged 2.45%, were similar with either irrigation method. However, plant N concentration was higher with overhead than with drip irrigation with the lower N-K rate but with the higher rate, squash plant N concentration was not affected by irrigation method. Fertigation at the higher N-K rate maintained soil nutrients at an adequate level for plant uptake, and reduced the effect of leaching associated with drip irrigation which was apparent at the lower application rate. Plant N concentration with residual and concurrent fertilization averaged 2.03%. Thomas and McLean (92) reported a 2.5-6.0% range of N concentrations for squash plants grown in greenhouse sand cultures and sampled 8 weeks after emergence. They suggested 5%

N as the critical level of plant N. The earlier time of sampling and the higher rates of nutrient application in their study, and the lack of any fertilization in the fall time of application plots in this study resulted in the differences reported.

In the first year, broccoli leaf, head and plant P concentrations were higher with drip than with overhead irrigation but only the early leaf and head samples were affected significantly. This response was due to the higher soil moisture percentage with drip than with overhead irrigation which resulted in increased concentration of water soluble P with drip than with overhead irrigation, especially at Gainesville. Average soil P concentrations were 0.62 and 0.44 ppm for drip and overhead irrigated plots, respectively. Bacon and Davies (5) presented evidence showing that rapid large scale release of both native and applied P occurs during the "wet" portion of each irrigation cycle in a sandy clay loam soil. They further reported significant correlations between P availability and soil water content, and concluded that drip irrigation could lead to management systems in which the necessity for P fertilization is reduced. They attributed this effect to reduction of ferric phosphates to ferrous phosphates in anaerobic microsites. Leaf P concentrations in this study were similar to values reported by Peck and MacDonald (71) but were much higher than the 0.13% obtained by Magnifico et al. (64). Head and plant P concentrations, which averaged 0.86 and 0.58%, also were much higher than the values reported by Magnifico et al. (64).

In 1984, broccoli leaf P concentration was higher with drip than with overhead irrigation. At Gainesville, head P concentration was

higher with drip than with overhead irrigation with fall + fall fertilization but with residual fall + spring N-K application, the opposite effect occurred. Soil pH 2 weeks after heads were sampled was 6.28 and 6.56 for fall + spring fertilized, overhead and drip irrigated plots. Since soil P availability generally decreases as pH increases above 6.5, the reduced broccoli head P concentration with drip irrigation may be an effect of increased soil pH. Also, with residual fall + spring fertilization, plant growth was more vigorous and dry matter accumulation was greater with overhead than with drip irrigation, due to higher levels of residual soil nutrients. A more extensive root system probably developed which increased the soil volume contacted by overhead irrigated plants and increased P uptake. Broccoli plant P concentrations with fall + fall fertilization were 0.58 and 0.51% with drip and overhead irrigation, but with fall + spring nutrient application, plant P concentration was not affected by irrigation method. However, total plant P accumulation with residual fall + spring fertilization was greater with overhead than with drip irrigation due to increased plant dry matter accumulation.

Tomato leaf and fruit P concentrations were not affected by irrigation method. Leaf P concentration decreased from 0.60 to 0.32% from 7 to 14 weeks after transplanting. Similar leaf concentrations and decreases with time were reported by Locascio et al. (61) for drip irrigated tomatoes. Others (39,91) also reported tomato leaf P concentration decreased with time, but obtained lower values than in this study. At Gainesville with either N-K application time or at

Quincy with residual fall fertilization, tomato plant P concentrations were not affected by irrigation method but at Quincy with fall + spring fertilization, plant P concentration was 0.20% with overhead and only 0.14% with drip irrigation. Tissue P concentration in squash has been shown to decrease with an increase in soil soluble salts (34). The higher soil N and K concentrations maintained throughout the season with drip fertigation may have contributed to the low plant P concentration at Quincy. The average concentrations of 0.50 and 0.40% P for fruit and plant samples were similar to those obtained by Halbrooks and Wilcox (39) and Pica and Hall (74) for determinate tomato varieties but were higher than values reported by Tanaka et al. (91) for indeterminate, topped tomatoes.

Squash leaf P concentration at Quincy with residual fall fertilization was 0.68% with overhead and 0.53% with drip irrigation, but with fall + spring N-K application or at Gainesville with either time of application, irrigation method did not influence leaf P concentration. Fruit P concentration 6 weeks after emergence averaged 1.00% and was not affected by irrigation method. At 10 weeks after emergence, fruit P concentration decreased to 0.85% with drip and 0.78% with overhead irrigation. Plant P concentration was not affected by irrigation method. The 0.60% average leaf P concentration was higher than the 0.38% reported by Francois (34) for zucchini and scallop squash leaf blades and the plant P concentration of 0.59% exceeded the 0.50% critical level of Thomas and McLean (92) for yellow squash.

Broccoli leaf and head K concentrations were not affected by irrigation method in 1983. With the lower N-K rate, plant K concentration was 3.76% with overhead and 3.11% with drip irrigation but with the higher rate, irrigation method did not affect plant K concentration. Although the higher soil moisture with drip irrigation leached soil K, with the higher N-K application rate with weekly drip fertigation, adequate soil K concentration was maintained and plant K concentration averaged 4.03%. The average leaf K concentrations of 2.93 and 2.49% at 4 and 9 weeks after transplanting are lower than the season average 3.8% reported by Magnifico et al. (64) for a late maturing variety (6 months) but higher than the 1.1-2.7% obtained by Peck and MacDonald (71) for leaf blades sampled 9 weeks after seeding an early maturing cultivar.

In 1984, with either N-K rate at Gainesville and with the lower rate at Quincy, leaf K concentration was higher with overhead than with drip irrigation, but at Quincy with the higher rate, irrigation method did not influence broccoli leaf K. At 6 weeks after transplanting, only 75% of the scheduled N-K had been applied to the drip irrigated plots while 100% had been applied to the overhead irrigated treatmnts. The difference in K applied was reflected in leaf tissue K concentrations. At Quincy with weekly drip fertigation at the higher rate, even though the total K applied was lower than with overhead irrigation, adequate soil K concentration was maintained, and leaf K concentrations were similar with either irrigation method. Broccoli head and plant K concentrations were higher with drip than with overhead irrigation with concurrent fall +

fall fertilization but with residual fall + spring nutrient application, the opposite effect occurred. The increased values obtained with drip irrigation with concurrent fertilization resulted from the higher soil K levels later in the season with weekly fertigation. The lower tissue K concentrations with drip with the residual nutrient treatment reflected low soil K due to leaching.

Average leaf and plant K concentrations were higher in 1984 than in 1983 while head K concentration were similar. The increased values in the second year may reflect higher soil K levels following a year of continuous cropping.

Tomato leaf, fruit and plant K concentrations were higher with overhead than with drip irrigation but only in the 2nd leaf samples was the difference significant. Residual soil K concentrations following 1983 broccoli were much higher with overhead than with drip irrigation, which, when combined with the delayed N-K application with weekly drip fertigation, produced the observed effect. Locascio et al. (60) obtained higher drip irrigated tomato leaf K concentrations at 4 and 6 weeks after transplanting with 100% preplant N-K application than with 40% preplant and 60% injected weekly. In this study, average leaf K concentrations were 2.50 and 1.83% at 7 and 14 weeks after transplanting. Locascio et al. (60) obtained 2.00 and 1.25% K for tomato leaf sampled 6 and 15 weeks after transplanting but in another study (62) reported values of 2.88 and 2.28% K at 7 and 13 weeks. The decrease in tomato leaf K concentration from 7 to 14 weeks was similar to that reported by Widders and Lorenz (93) who found tomato leaf K concentration decreased by 20-30% with fruit

maturation. Others (39,54,91) have reported a similar response. Fruit K concentration was similar to values obtained by Halbrooks and Wilcox (39) and Widders and Lorenz (93), but was higher than K concentrations reported for mature green fruit by Locascio et al. (60), Pica and Hall (74) or Tanaka et al. (91). Average plant K concentration of 2.25% was similar to other reported values (39,91).

Squash leaf and fruit K concentrations 6 weeks after emergence were higher with overhead than with drip irrigation, but only fruit K concentration was affected significantly. At that time, only 60% of the scheduled K had been applied to the drip irrigated plots, while 100% had been applied before seeding to the overhead irrigated plots. Fruit K concentration at 10 weeks was similar with either irrigation method even though the drip irrigated plots had received only 90% of the total N-K treatments. Plant K concentrations at Gainesville with either application time and at Quincy with fall + spring fertilization, were not affected by irrigation method. However, at Quincy with residual fall N-K application, squash plant K concentration was higher with overhead than with drip irrigation. Residual soil K concentration was significantly higher with overhead than with drip irrigation at that location as a result of leaching of mobile soil nutrients with drip irrigation. The average squash leaf K concentration of 4.67% obtained in this study was slightly higher than the maximum 4.01% K reported by Francois for zucchini squash leaf blade 9 weeks after emergence, but leaf K concentration probably decreases with continued fruit production, as has been reported for tomato (39,54,60,61,62,91,93). The 4.02% average plant K

concentration is within the sufficiency range of 2.0-8.5% reported for greenhouse-grown yellow straightneck squash by Thomas and McLean (92).

Broccoli leaf Ca concentration 4 weeks after transplanting in 1983 was not affected by irrigation method but 9 weeks after transplanting, leaf Ca concentration at Quincy with the higher N-K application rate was 2.91% with overhead irrigation and 2.51% with drip. The average leaf Ca concentrations of 3.35 and 2.73% at 4 and 9 weeks after transplanting were much higher than the 1.3-2.1% range reported by Peck and MacDonald (71) for broccoli leaf 9 weeks after seeding. Head Ca concentration was 0.54% with overhead and 0.48% with drip irrigation, but plant Ca concentrations, 2.50 and 2.26% with overhead and drip irrigation, did not differ significantly. Soil Ca concentration, sampled 11 weeks after transplanting was higher with overhead than with drip irrigation, although the difference was significant only at Quincy. Apparently, leaching of soil Ca occurred with drip irrigation, and this was reflected in some of the broccoli tissue. Previous studies (36,37,58,67) with drip and overhead irrigation and mulched beds has shown that mobile soil nutrients move down and out of the root zone with drip irrigation, and upwards towards the soil surface with overhead irrigation.

In 1984, broccoli leaf Ca concentration 6 weeks after transplanting at Gainesville with fall + fall fertilization and at both locations following squash with fall + fall fertilization was higher with overhead than with drip irrigation. The fall + fall overhead irrigated plots received 100% of the scheduled N-K prior to transplanting while the drip irrigated plots had received only 75% of

that amount at 6 weeks after transplanting. Since increased soil soluble salt concentration is known to reduce plant Ca uptake, the effect observed probably was due to different scheduling of fertilizer application, rather than the irrigation methods themselves. Broccoli head and plant Ca concentrations were not influenced by irrigation method directly.

Tomato leaf, fruit and plant Ca concentrations were not influenced by irrigation method. Leaf Ca concentration increased from 2.13 to 3.64% from 7 to 14 weeks after transplanting. Similar responses and values have been reported by Locascio et al. (61) and Tanaka et al. (91). Fruit Ca concentration averaged 0.17% which was similar to concentrations reported by others (39,74) but was lower than the 0.50% obtained by Tanaka et al. (91). Average plant Ca concentration was within the 2.68-3.28% range of Halbrooks and Wilcox (39).

Squash leaf Ca concentration 6 weeks after emergence was 2.61% with drip and 2.26% with overhead irrigation. However, Ca concentrations in fruit sampled at the same time or 4 weeks later, and in plants 11 weeks after emergence, were not affected by irrigation method. Francois (34) reported higher leaf Ca concentrations for both summer and winter squash varieties produced with application of high levels of Ca.

In 1983, broccoli leaf Mg concentration was not influenced by irrigation method 4 weeks after transplanting but in all later samples, tissue Mg concentrations were higher with overhead than with drip irrigation. Soil Mg concentrations were higher with overhead

than with drip irrigation due to leaching with drip irrigation. The higher level of fertilizer salts in the soil later in the season with the weekly drip fertigation contributed to the observed effect by reducing plant Mg uptake. The average leaf Mg concentrations of 0.58 and 0.43% were similar to values reported by other researchers (71).

Broccoli leaf and head Mg concentrations were not influenced by irrigation method in 1984, but plant Mg concentrations were 0.44 and 0.42% with overhead and drip irrigation. Values were similar to those obtained in 1983.

Tomato leaf Mg concentrations 7 weeks after transplanting averaged 0.57%, but at 14 weeks after transplanting, leaf Mg concentrations were 0.59% with overhead and 0.53% with drip irrigation. Fruit Mg concentration was 0.19% with either irrigation method. Plant Mg concentrations averaged 0.60% at Gainesville but at Quincy, Mg concentrations were 1.02% with overhead and 0.78% with drip irrigation. Heavy rainfall at Quincy combined with the high soil moisture associated with drip irrigation to leach soil Mg out of the root zone. Locascio and Myers (58) reported similar higher leaching of soil soluble salts with drip than with overhead irrigation in a heavy rainfall season. Leaf, fruit and plant Mg concentrations were similar to those reported by other researchers (39,61,74,91).

Squash leaf Mg concentrations were 0.80% with drip and 0.68% with overhead irrigation, but fruit and plant concentrations were not affected by irrigation method. The higher soil fertilizer salts with overhead irrigation which resulted from 100% preplant N-K application as compared to only 60% with drip fertigation, decreased early Mg

uptake. Leaf Mg concentrations were within the range of values reported by Francois (34) for samples taken ten weeks after planting.

Rate of N-K Application

Broccoli leaf, head and plant N concentrations increased with an increase in N-K rate in 1983. The rate of increase in leaf N was greater with drip than with overhead irrigation at 9 weeks after transplanting. Others (60) have reported higher soil N concentrations at 8 and 12 weeks after transplanting tomato with weekly drip fertigation than with 100% preplant fertilization. The higher soil N would be reflected in higher tissue N concentrations.

In 1984, leaf N concentration 6 weeks after transplanting was not affected by N-K rate at Gainesville with either time of application or at Quincy with concurrent fall + fall fertilization but with residual fall + spring fertilization, leaf N concentrations were 2.95% with the lower N-K rate and 3.37% with the higher N-K rate. Residual concentrations of NO_3-N and NH_4-N in the soil were higher with 270-404 than 135-202 $kg \cdot ha^{-1}$ N-K applied to the spring crops. Head and plant N concentrations increased with an increase in N-K application rate.

Tomato leaf, fruit and plant N concentrations were not influenced by application rate. The absence of response to rate of fertilizer application was contrary to results reported by Persaud et al. (73). They obtained linear increases in tomato leaf N concentration as application rate increased from 101-111 to 303-333 $kg \cdot ha^{-1}$ N-K on similar soils with both overhead and drip irrigation. In this study, high soil moisture due to heavy leaching rains may have reduced soil N concentrations, which was reflected in plant tissues. At Quincy, for

example, poor drainage resulted in standing water to the tops of the mulched beds on several occasions following heavy rains.

Squash leaf and fruit N concentrations also were not affected by N-K rate but plant N concentrations were 2.33 and 1.72% with the higher and lower rates, respectively. The rate of increase in squash plant N concentration was greater with drip than with overhead irrigation. The higher soil N concentration with the more timely weekly drip fertigation compensated for the nutrient losses and movements previously discussed.

In 1983, broccoli leaf P concentrations 4 weeks after transplanting were similar with either N-K rate, but later leaf, head and plant P concentrations increased with an increase in N-K rate. Peck and MacDonald (71) reported that broccoli leaf P concentration 9 weeks after seeding was not affected by increased rates of K from 0 to 560 $kg \cdot ha^{-1}$. However, they did not examine more mature tissue. In this study, more vigorous plant growth with the higher than lower N-K rate enabled a more extensive root system to contact and uptake increased quantities of P from the soil.

Similar results were obtained in 1984. Broccoli leaf P concentration 6 weeks after transplanting was not affected by N-K rate. At Gainesville, head and plant P concentrations increased with an increase in N-K rate, but at Quincy, N-K rate did not affect head or plant P concentrations. Lower water soluble P levels at Quincy than at Gainesville may have limited P uptake even with more vigorous plant growth.

Tomato leaf P concentration 7 weeks after transplanting decreased with an increase in N-K rate. Later leaf P concentration was not affected by N-K rate except at Gainesville where with residual fall fertilization and overhead irrigation, leaf P concentration decreased from 0.57 to 0.45% as N-K rate increased. Fruit P concentration decreased as N-K rate increased only at Gainesville with concurrent fall + spring N-K application and overhead irrigation, but total P accumulated by tomato fruit was similar with either rate due to increased fruit yield with the higher N-K rate. Tomato plant P concentration was not affected by application rate; however, total P accumulated by the plant was greater with the 270-404 $kg \cdot ha^{-1}$ N-K rate due to increased dry matter production with the higher than lower rate. Persaud et al. (73) obtained a linear decrease in early tomato leaf P concentration as N-K rate increased from 101-111 to 303-333 $kg \cdot ha^{-1}$. No data were presented for fruit or plant tissue. Pica and Hall (74) reported that K application rate did not affect fruit pericarp P concentration within a range of 0 to 744 $kg \cdot ha^{-1}$.

Squash leaf P concentration decreased from 0.63 to 0.56% with an increase in N-K rate. Francois (34) reported decreased leaf P concentrations as soil soluble salts increased for both zucchini and scallop squash. Fruit P concentration 6 weeks after emergence also decreased as N-K rate increased but the difference was not significant. Later fruit and plant tissue P concentrations were lower with the higher rate, but the effect was significant only with residual fall fertilization. However, with fall nutrient application more P accumulated in both fruits and plants with the higher than the

lower N-K rate due to increased fruit yield and plant dry matter accumulation with the higher rate. In a series of greenhouse pot nutrient studies, Thomas and McLean (92) varied N and K application rates separately and reported that increasing rates of either nutrient resulted in decreased P concentration of squash whole plant tissue sampled 8 weeks after transplanting. Increased N rates decreased plant P concentration by "dilution," i.e., increased plant dry matter production while plant P uptake remained the same, while increased K rates decreased plant P concentration due to ion antagonism.

In 1983, broccoli leaf and plant K concentrations increased with an increase in N-K rate but head K concentration was 4.20% with either rate. Peck and MacDonald (71) reported a similar increase in broccoli leaf K concentration as K application rate increased from 0 to 560 $kg \cdot ha^{-1}$. The rate of increase of broccoli plant K concentration was greater with drip than with overhead irrigation, probably due to leaching of soil K with drip. At the higher N-K rate, a higher level of soil K was maintained by weekly drip fertigation through the season, and plant K concentrations were similar with either irrigation method.

In 1984, all broccoli tissue K concentrations were higher with the higher than lower N-K application rate. However, at Quincy, leaf K concentration with overhead irrigation and head and plant K concentrations were not affected significantly.

Tomato leaf and plant K concentrations increased with an increase in N-K rate. Fruit K concentration also increased, but the effect was not significant. Similar effects of N-K rate on tomato leaf K

concentration were obtained by Persaud et al. (73) but Pica and Hall (74) reported that fruit pericarp K concentration increased from 1.67 to 2.98% as K application rate increased from 0 to 744 $kg \cdot ha^{-1}$.

Potassium concentrations of squash leaf and fruit 6 weeks after emergence, and squash plant 11 weeks after emergence were higher with the higher than lower N-K application rate. The later fruit K concentration was not affected by N-K rate except at Gainesville with overhead irrigation and residual fall fertilization; fruit K concentrations were 5.14 and 4.28% with the 135-202 and 270-404 $kg \cdot ha^{-1}$ N-K rates, respectively. However, total K accumulation by the fruit was greater with the higher rate due to the much higher yield. Thomas and McLean (92) obtained higher plant K concentration with an increase in K application rate but reported that increased N application rate did not affect plant K concentration, due to increased dry matter accumulation at the higher rate.

In 1983, broccoli leaf Ca concentration 4 weeks after transplanting was not influenced by N-K rate. Leaf Ca concentration later in the season was not affected by N-K rate with overhead irrigation; however, with drip irrigation at Gainesville, leaf Ca concentration increased with N-K rate while at Quincy, the opposite effect occurred. Head Ca concentration was 0.51% with either N-K rate but plant Ca concentration increased from 2.28 to 2.47% as N-K rate increased from 135-202 to 270-404 $kg \cdot ha^{-1}$. Levels of Ca in all tissues were adequate to meet plant requirements (71), even though concentrations varied some with treatments.

Broccoli leaf Ca concentration in 1984 was not affected by N-K rate at Gainesville, but decreased from 3.48 to 3.14% with an increase in N-K rate at Quincy. Peck and MacDonald (71) reported a decrease in broccoli leaf blade Ca concentration from 2.1 to 1.3% as K rate increased from 0 to 560 $kg \cdot ha^{-1}$. Head and plant Ca concentrations were not affected by N-K rate.

Tomato leaf Ca concentration 7 weeks after transplanting and fruit and plant Ca concentrations were not influenced by N-K rate. Leaf Ca concentration 14 weeks after transplanting at Gainesville or with overhead irrigation, was higher with the lower N-K rate. Higher soil soluble salts with the higher N-K rate and overhead irrigation probably increased ion competition which reduced uptake of Ca by the plant. Pica and Hall (74) reported that rate of soil K application did not affect fruit Ca concentrations.

Squash tissue Ca concentrations responded similarly. Leaf, fruit and plant Ca concentrations decreased with an increase in N-K rate although the effects on leaf concentration and fruit concentration at Quincy 6 weeks after emergence were not significant. Francois (34) reported an increase in leaf Ca concentration as soluble salt concentration increased, but the salt applied was $CaCl_2$ which also increased Ca applied.

Broccoli leaf Mg concentration 4 weeks after transplanting in 1983 decreased from 0.60 to 0.55% with an increase in N-K rate. Later leaf tissue Mg concentration at Quincy decreased from 0.58 to 0.53%, but at Gainesville, leaf Mg concentration was not affected by an increase in N-K rate. Broccoli head Mg concentration averaged 0.28%,

but plant Mg concentration increased slightly from 0.41 to 0.44% with an increase in N-K rate.

In 1984, broccoli leaf Mg concentration decreased with an increase in N-K rate but the effect was significant only at Quincy. Head Mg concentrations were similar with either N-K rate, and plant Mg concentration was affected by N-K rate only at Gainesville with residual fertilization and overhead irrigation.

Tomato leaf, fruit and plant Mg concentrations were not affected by N-K application rate.

Squash leaf Mg concentration decreased from 0.79 to 0.69% with an increase in N-K rate, but the Mg concentration of fruit sampled at the same time was not affected by N-K rate. Later fruit and plant Mg concentrations also decreased with an increase in N-K rate, but the effect was significant only at Quincy. Francois (34) obtained a linear increase in leaf Mg concentration with zucchini squash as soluble salts increased, but with scallop squash, concentration of soluble salts did not influence leaf Mg concentration.

Time of N-K Application

Broccoli leaf, head and plant tissue N and K concentrations in 1984 were higher with concurrent fall + fall than residual fall + spring time of N-K application. Low residual soil N and K levels following both squash and tomato were reflected in subsequent plant tissues.

Tomato leaf, fruit and plant N and K concentrations also were higher with concurrent than residual fertilization, but the effect on N concentration was not significant in the later leaf and plant

tissues. Plant N concentration at Gainesville with drip irrigation was 2.42% with residual fall N-K application, and 1.70% with concurrent fall + spring fertilization. Tomato yield was lowest with the drip irrigated, residual fertilization treatment, which reduced the sink for translocation of N from the plant, and resulted in higher plant N concentration. Also, plant dry matter production was much higher with concurrent than residual fertilization, and total N accumulated in the plants was almost 50% higher with fall + spring than fall fertilization; the lower N concentration in fall + spring fertilized, drip irrigated tomato plants was due in part to a dilution effect.

Nitrogen and K concentrations of all squash tissues were higher with concurrent fall + spring than with residual fertilizer time of N-K application due to low residual soil N and K concentrations following fall broccoli.

Broccoli leaf P concentration 6 weeks after transplanting was higher with fall + fall than with residual fall + spring time of N-K application at Gainesville with overhead irrigation and at Quincy with drip. At Gainesville, head and plant P concentrations were higher with concurrent than residual fertilization, but at Quincy, time of application did not influence head or plant P concentrations. More vigorous plant growth with concurrent than residual fertilization enabled a more extensive root system to contact and remove more P from the soil; lower water soluble P levels at Quincy than at Gainesville may have limited P uptake even with the more extensive root system. Total quantities of P removed from the soil by plant and head were 63

and 178% higher with concurrent than residual N-K application due to increased dry matter accumulation and higher yields.

Tomato leaf P concentrations 7 weeks after transplanting were 0.63 and 0.57% with fall and fall + spring time of application, but 7 weeks later decreased to 0.48 and 0.38%, respectively, at Gainesville and averaged only 0.21% at Quincy. Tomato fruit P concentration was not influenced by N-K application time except at Gainesville with overhead irrigation and the 135-202 $kg \cdot ha^{-1}$ N-K rate; that fruit P concentration averaged 0.58 and 0.69% with fall and fall + spring application times. Plant P concentration was higher with residual fall than concurrent fall + spring fertilization except at Quincy with overhead irrigation where values were similar with either treatment. Again, total P accumulation by plant and fruit were much higher (43 and 69%) with fall + spring than with residual fall N-K application time, and lower concentrations of P in tissues were due to a dilution effect related to greater plant dry matter production and higher fruit yields.

Squash leaf P concentrations at Gainesville with either irrigation method and at Quincy with overhead irrigation, were higher with residual than concurrent fall + spring application time but at Quincy with drip irrigation, the opposite effect was observed. The low concentrations of residual nutrients with drip irrigation reduced early plant growth and prevented the development of an extensive root system. Low soil P availability at Quincy in conjunction with a poor root system reduced P uptake and resulted in low leaf P concentration with drip irrigation and residual fertilization. Fruit and plant P

concentrations were lower with concurrent fall + spring application time than with residual fall fertilization due to dilution. Total P accumulations by plant and fruit tissues were 90 and 185% higher with concurrent than residual time of N-K application.

Broccoli leaf Ca concentrations in 1984 averaged 4.07 and 3.32% with concurrent fall + fall and residual fall + spring N-K application time, respectively, with drip irrigation, but with overhead irrigation, leaf Ca concentration was not affected by application time. Poor plant growth with residual nutrient application and drip irrigation probably reduced Ca uptake. Calcium absorption occurs primarily at root tips where the Casparian strip has not developed. Thus new, active root growth is required for Ca uptake, and any condition which limits root growth can reduce Ca accumulation. Head Ca concentrations were 0.76 and 0.72% with residual and concurrent fertilization; however, total Ca accumulated was much greater with fall + fall than residual fall + spring N-K application due to the significant difference in dry matter production. The greater amount of Ca in the heads was diluted by an even greater accumulation of dry matter. Soil soluble salt concentrations, especially K, were higher with concurrent than with residual fertilization, and probably reduced Ca uptake. Peck and MacDonald (71) reported decreased leaf Ca concentration in response to increased K application rate. They did not examine head or whole plant tissue. Plant Ca concentration at Quincy averaged 2.48% but at Gainesville, Ca concentrations were 3.17 and 2.59% with fall + fall and fall + spring N-K application. Tomato leaf Ca concentrations were higher with residual fall than with fall +

spring N-K application time, but fruit Ca concentration was not affected. At Quincy, plant Ca concentrations were 3.01 and 2.39% with fall and fall + spring fertilization, but at Gainesville, plant Ca concentration was not influenced by application time. At both locations, total Ca accumulation by plants and fruit was greater with concurrent than residual fertilization, but tissue Ca concentrations did not reflect this due to dilution effect.

At Gainesville, squash leaf Ca concentration was 3.08%, but at Quincy, leaf Ca concentration was lower with concurrent than with residual fall fertilization. The decrease was greater with overhead than with drip irrigation due to the higher soil soluble salt concentration with the 100% preplant fertilization with overhead irrigation. At the time of sampling, only 60% of the scheduled N-K had been applied with weekly drip fertigation. Calcium concentration of fruit sampled at the same time was 0.33% with overhead irrigation but with drip irrigation, fruit Ca concentrations were 0.29 and 0.34% with fall and fall + spring application time. Fruit Ca concentration 4 weeks later was lower with fall + spring than fall fertilization with both irrigation methods, but the effect was greater with drip irrigation. The early fruit Ca concentration was lowest with residual fertilization and drip irrigation as a result of less vigorous plant growth. Highest total fruit yields were obtained with concurrent fertilization and drip irrigation. The lower fruit Ca concentration associated with that treatment combination was another example of the dilution effect. Squash plant Ca concentration was not affected by N-K application time with the lower N-K application rate. With the

higher N-K rate, plant Ca concentrations were 4.02 and 3.29% with fall and fall + spring times of application. The lower value associated with concurrent fertilization was due in part to ion antagonism as well as a dilution effect. Plant dry weights averaged 78.7 and 131.3 g with fall and fall + spring fertilization at the higher N-K rate.

Broccoli leaf Mg concentration was not influenced by time of N-K application. Head and plant Mg concentrations at Quincy averaged 0.28 and 0.48%, respectively, but at Gainesville, both were lower with residual fall + spring than concurrent fall + fall fertilization. Larger plants with more extensive root systems developed with concurrent than with residual fertilization, and increased uptake of Mg resulted.

Tomato leaf Mg concentrations were not affected by time of N-K application but fruit Mg concentrations were 0.20 and 0.19% with concurrent fall + spring and residual fall fertilization. Tomato plant Mg concentration at Gainesville was not influenced by application time but at Quincy with the 270-404 $kg \cdot ha^{-1}$ N-K rate, plant Mg concentrations were 1.11 and 0.73% with residual and concurrent fertilization. Plant dry matter accumulation was greater with concurrent than residual N-K application and the lower Mg concentration was due to the dilution effect.

At Gainesville with overhead irrigation, squash leaf Mg concentration was not affected by N-K application time but with drip irrigation, leaf Mg concentrations were 0.83 and 0.63% with fall and fall + spring fertilization. Increased plant growth and greater dry

matter accumulation occurred with fall + spring N-K application and drip irrigation, and total Mg accumulated was higher, but leaf concentration was lower due to dilution. At Quincy, leaf Mg concentrations were higher with residual than with fall + spring fertilization, but the effect was greater with overhead irrigation. Again, dilution was primarily responsible but with overhead irrigation, the difference in total Mg accumulated was not as great as the effect on leaf Mg concentration. Part of the effect may be a result of decreased uptake with fall + spring application and overhead irrigation due to antagonism caused by high soil soluble salts. Magnesium concentrations of fruit 6 weeks after emergence and plants were not affected by N-K application time with the 135-202 $kg \cdot ha^{-1}$ N-K rate but with the higher rate, tissue Mg concentrations were lower with fall + spring than with fall fertilization. Fruit Mg concentrations 10 weeks after emergence were 0.39 and 0.36% with residual fall and concurrent fall + spring N-K application. Increased fruit yield and plant dry matter production fall + spring as compared to fall fertilization reduced tissue Mg concentrations. Higher soil soluble salts with the higher N-K application rate probably contributed to the observed effect.

Crop Sequence

Broccoli leaf, head and plant N, K and Mg concentrations were not affected by crop sequence.

Leaf P concentrations 6 weeks after transplanting were 0.74 and 0.70% following squash and tomato, respectively. Head and plant P concentrations were not influenced by preceeding crop. Residual soil

soluble salts, including NO_3-N, NH_4-N and K, were higher following squash than tomato. Early plant growth following squash probably was enhanced, with more vigorous root growth, which resulted in increased P uptake. Total P accumulation, however, was higher following tomato than squash, due to increased dry matter production.

Leaf and head Ca concentrations were not affected by crop sequence, but plant Ca concentration with overhead irrigation was 2.84% following tomato, and 2.56% after squash. Plant growth and dry matter accumulation were greatest with overhead irrigation and with tomato as the preceeding crop. The more extensive root system increased Ca uptake from the soil as compared to the other treatment combination.

Soil Chemical Characteristics

At Gainesville with overhead irrigation, soil pH values were 6.33 and 6.34 at the beginning and end of the cropping sequence but with drip irrigation, soil pH increased slightly from 6.36 to 6.52 over the same time period. At Quincy, soil pH decreased with both irrigation methods over the 15 month period of the field trials. Irrigation water Ca and Mg concentrations were 66 and 16 ppm at Gainesville and 20 and 10 ppm at Quincy. The short-term liming effect of the irrigation water at Gainesville was 2.5 times that at Quincy. The 900 mm of irrigation water applied at Gainesville had an aglime equivalent of 3.6 $t \cdot ha^{-1}$. The lower equivalence with the similar water quantity applied at Quincy was not sufficient to prevent pH reduction due to leaching of bases and acidification associated with fertilizer application. The slight increase in soil pH with drip

irrigation at Gainesville probably resulted from the direct application of water under the plastic mulch.

At the center and side of the bed and at all depths, average soil EC and concentrations of NO_3-N, NH_4-N, K, Ca and Mg were higher with overhead than with drip irrigation after all crops. Soil P concentrations, however, were higher with drip than with overhead irrigation or were similar with either irrigation method. Higher soil moisture with drip than with overhead irrigation leached mobile soil nutrients from the soil profile, but increased the amount of P released into the soil solution. With overhead irrigation, soluble salts accumulation was greater at the center than at the side of the bed, and decreased with depth at both bed locations. With drip irrigation, soluble salts generally were higher at the side than at the center of the bed, and decreased with depth only at the side; values at the center were low and similar at all depths. Similar effects of overhead and drip irrigation on soil nutrient distribution have been reported (5,37,46,49,58,59,73).

Concentrations of soluble salts, NO_3-N and K consistently were higher with the 270-404 than the 135-202 $kg \cdot ha^{-1}$ N-K rate, and NH_4-N, Ca and Mg concentrations increased with N-K rate occasionally, but soil P concentrations were not influenced by N-K rate.

Soil soluble salts and concentrations of NO_3-N, NH_4-N, K and Ca were higher with concurrent than residual fertilization of all crops. Concentrations of P and Mg were not affected by time of N-K application. Others (19,30) have reported similar effects of time of N-K application on soil soluble salts.

Residual soil EC NO_3-N, NH_4-N and K values were higher after squash than tomato but sequence did not affect soil nutrient concentrations following the subsequent 1984 broccoli crop.

Soil Moisture

Daily soil moisture percentage, sampled prior to application of irrigation, was higher with drip than with overhead irrigation on all 3 days. Other researchers (7,59) also obtained higher levels of soil moisture with drip than overhead irrigation. With overhead irrigation soil moisture percentage increased with irrigation after sampling on Day 1, but decreased rapidly from Day 2 to Day 3, while with daily application, drip irrigation maintained a higher, constant level of soil moisture over the 3-day period. Similar soil moisture responses to overhead and drip irrigation were reported by Myers and Locascio (67) in mulched strawberry plots on a fine sand soil. With overhead irrigation, the plastic mulch acted as a barrier to water movement into the beds. Standing water was observed in the row middles following water application with overhead irrigation while with drip irrigation, row middles remained dry. With both irrigation methods, soil moisture percentage was higher at the center than at the side of the bed but the difference was greater with drip than with overhead irrigation. With drip irrigation, all the water was applied at the center of the bed but with overhead irrigation, water entered the bed through holes in the center where the tomato plants were set, and through holes in the side where the fall broccoli plants had been set, and laterally from the row middles. Soil moisture increased linearly with an increase in soil depth. Locascio et al. (62) obtained similar

values for the same type soil with water applied at 0.5 ET_{pan} to the plot area with drip irrigation under plastic mulch. With the quantity applied increased to 1 ET_{pan}, values were higher at each depth and increased with an increase in soil depth to 30 cm. Kafkafi and Bar-Yosef (46) obtained similar moisture distribution with drip irrigation water applied at 0.4 and 0.65 ET_{pan} on a coarse, calcareous soil without mulch. In this study water was applied at 0.5 and 1.0 ET_{pan} with drip and overhead irrigation, respectively, yet at all depths, locations and times of sampling, soil moisture percentage was significantly higher with drip than with overhead irrigation. The soil moisture percentage at field capacity for this soil ranged from 4.56 to 4.93%, so both methods maintained adequate levels of soil moisture for crop growth. However drip irrigation maintained a more stable root environment with one-half the water quantity than did overhead irrigation. The high levels of soil moisture with drip irrigation may result in leaching of soil nutrients (6,37). Other researchers (58,73) have reported increased leaching of nutrients under plastic mulch with drip as compared to overhead irrigation with one-half the quantity of water applied. Locascio et al. (61) reported similar early, mid and total season yields of drip irrigated tomatoes with water quantities of 1.0 and 2.0 ET_{pan}, and 0.5 and 1.0 ET_{pan} in a 2-year greenhouse study. Apparently, weekly nutrient fertigation can compensate for nutrient leaching with higher water application quantities; however, with residual nutrients, the higher soil moisture with drip irrigation may increase leaching, and result in reduced crop yields, as previously discussed.

CHAPTER 6
SUMMARY

Tomato, squash and broccoli were produced successfully as 2nd or 3rd crops on black polyethylene mulch. However, with mulched crop production, fertilization management practices for optimum yields differ with irrigation method. Yields of successively cropped tomato and broccoli produced with residual fertilizer were low with drip irrigation. Yields of both crops were higher with overhead than drip irrigation, but were much lower than average commercial yields reported for north Florida (33). With residual N-K fertilization, tissue mineral concentrations, except P, were lower with drip than with overhead irrigation, indicating reduced concentrations of available nutrients in the soil. Soil nutrient concentrations generally were higher with overhead than drip irrigation due to leaching of soil nutrients which resulted with drip irrigation. Successive cropping of vegetables with high nutrient requirements will require fertilization for acceptable yields with drip irrigation. Yield of unfertilized yellow squash following fertilized fall broccoli averaged 9.3 and 17.1 $t \cdot ha^{-1}$ with drip and overhead irrigation, respectively. With the higher N-K rate in the fall, yield of overhead irrigated squash produced with residual nutrients averaged 24.7 $t \cdot ha^{-1}$, considerably higher than the state average of 8.1 $t \cdot ha^{-1}$

(33). Fall N-K application at the higher rate resulted in higher 1983 broccoli yield, increased early season large tomato yield at Gainesville and higher marketable and total tomato yields at Quincy. Residual soil nutrient levels were higher with the higher than lower N-K rate with both irrigation methods, but were higher with overhead than with drip irrigation due to leaching with drip. Some crops, with low nutrient requirements such as squash, may be produced with residual fertilizer from a previous crop, while others will require soils with higher nutrient holding capacities and management to reduce leaching. Increased rate of fertilization for the first crop may benefit 2nd crops under these circumstances. Leaching was more severe in the fine sand soil at Gainesville than in the loamy fine sand soil at Quincy. This was evidenced by the higher early season tomato yield at Quincy with residual than concurrent fertilization and the lack of yield response to increased N-K rate with concurrently fertilized tomato, squash and 1984 broccoli at that location.

With concurrent fall + spring fertilization, squash yields were 41.3 and 39.2 $t \cdot ha^{-1}$ with drip and overhead irrigation, respectively. In this study, production of squash probably was improved over average commercial yields by use of polyethylene mulch and irrigation, practices which are not common for that crop (51). With concurrent fertilization, drip irrigated tomato and broccoli yields also exceeded commercial yield averages and were equal to or higher than yields obtained with overhead irrigation. However, tissue mineral concentrations, especially N and K, were higher in most cases with overhead than drip irrigation. Soil nutrient concentrations

after each concurrently fertilized crop were higher with the 100% preplant N-K application with overhead irrigation than with the weekly drip fertigation, probably due to leaching of nutrients with drip irrigation. Although yields obtained with drip irrigation were similar to or higher than those with overhead irrigation, the drip irrigated crops were produced with 55% the water quantity that was used with overhead irrigation. Considerable savings in water use and associated pumping costs can be realized with drip as compared to overhead irrigation. In this study, drip irrigation water was applied to the plot area in a quantity equal to 0.55 ET_{pan} (1.0 ET_{pan} in the mulched bed). In other studies, with water applied to the root zone, the water quantity required for highest yield of drip irrigated tomatoes increased with plant growth from 0.3 to 0.4 ET_{pan} (6). Kafkafi and Bar-Yosef (46) obtained higher yields of drip irrigated tomatoes with water applied at 0.4 than 0.6 ET_{pan} to the plot area while others (62) reported similar tomato yields with water quantities of 0.25 and 0.5 ET_{pan} applied to the plot area. Apparently, a reduction in water application quantity with drip irrigation below that used in this study may be beneficial by reducing nutrient leaching without impairing plant growth and crop yield.

Tissue N concentrations in first crop broccoli and P concentrations in all crops were higher with drip than with overhead irrigation. Tissue concentrations of N in squash and K, Ca and Mg in all crops were higher with overhead than with drip irrigation. Tissue concentrations of N, P and K in broccoli, N and K in squash and K in tomato increased while concentrations of Ca and Mg in all crop tissues

and P in tomato and squash tissues decreased with an increase in N-K application rate. In all tissues, concentrations of N and K were higher, but Ca and Mg concentrations were lower, with concurrent than residual fertilization. In broccoli, tissue P concentrations were higher with concurrent than residual fertilization but in tomato and squash, the opposite effect was observed.

Most soil nutrient concentrations were higher with overhead than drip irrigation and with concurrent than residual nutrient application, and increased with an increase in N-K application rate. However, soil P concentrations were higher with drip than with overhead irrigation, but were not affected by rate or time of N-K application. With overhead irrigation, soil nutrient concentrations were higher at the center than at the side of the bed and decreased as depth increased. With drip irrigation, concentrations were higher at the side than center of the bed and decreased with an increase in depth at the side.

Production of broccoli, followed by tomato or squash, and broccoli resulted in more complete utilization of fertilizer, mulch and fumigant by prorating the costs of materials and labor over more than one crop. Production costs associated with land preparation and bed forming were eliminated for the 2nd and 3rd crops. With drip irrigation, water use was lower than with overhead. The reduced energy use and decreased production costs make the mulched bed, successive cropping system a viable, attractive alternative for vegetable production by both large and small-scale producers.

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BIOGRAPHICAL SKETCH

The author was born in Chicago, Ill., on Mar. 13, 1945. Upon completion of primary and secondary education in Trumbull, Ct., he entered military service. In 1974, after 11 1/2 years as an electronics technician in the U.S. Air Force, he began studies at the University of Florida, receiving a Bachelor of Arts degree in philosophy with a minor in environmental studies in 1977. In 1978, a Bachelor of Science in Agriculture degree in vegetable crops was awarded by the same university. Graduate study resulted in the granting of the Master of Science degree in horticultural science with a minor in agronomy (weed science) in 1981, also by the University of Florida. After 1 1/2 years of employment as an Assistant in Farming Systems with the Institute of Food and Agricultural Sciences, further graduate studies were begun at the University of Florida which culminated in 1986 with the award of the degree of Doctor of Philosophy in horticultural science with a minor in soil science.

The author is married to the former Silke E. Walsh and is the proud father of one child, Michael Damon.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

S. J. Locascio, Chairman
Professor of Horticultural Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

S. R. Kostewicz
Associate Professor of Horticultural Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

S. M. Olson
Associate Professor of Horticultural Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

D. A. Graetz
Associate Professor of Soil Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

A. B. Bottcher
Associate Professor of Agricultural Engineering

This dissertation was submitted to the Graduate Faculty of the College of Agriculture and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December, 1986

Dean, College of Agriculture

Dean, Graduate School